THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR Philip John McKinnon

TITLE OF THESIS Comparison of Broken Rice or Corn as Dietary Ingredients for Starting Pigs and Weanling Rats

DEGREE FOR WHICH THESIS WAS PRESENTED M.Sc.

YEAR THIS DEGREE GRANTED 1974

DATED Sept...

THE UNIVERSITY OF ALBERTA

COMPARISON OF BROKEN RICE OR CORN AS DIETARY INGREDIENTS FOR STARTING PIGS AND WEANLING RATS

BY

© PHILIP JOHN McKINNON

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

IN

ANIMAL NUTRITION

DEPARTMENT OF ANIMAL SCIENCE

EDMONTON, ALBERTA

FALL, 1974

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Comparison of Broken Rice or Corn as Dietary Ingredients for Starting Pigs and Weanling Rats" submitted by Philip John McKinnon, in partial fulfillment of the requirements for the degree of Master of Science.

Date Sept.........

ABSTRACT

Considerable quantities of broken rice are available as a livestock feed in rice growing areas of the world. An experiment was conducted in Thailand involving a total of 380 pigs in 52 litters to compare broken rice and ground corn as dietary ingredients for pigs from 3 to 10 weeks of age. Two further experiments were carried out with rats at the University of Alberta, Edmonton.

Dietary treatments in the pig experiment consisted of broken rice, corn, and 1/2 corn: 1/2 broken rice as major energy sources in test diets plus a control diet containing 20% dried skim milk. In the rat study, dietary treatments involved similar test diets of broken rice, corn and 1/2 corn: 1/2 broken rice fed at 20 or 14% dietary protein level in the two experiments, respectively.

Diets were introduced at 3 weeks in the pig experiment and fed through weaning at 5 weeks until 10 weeks of age. Evaluation criteria were 3, 5, 8 and 10-week body weight, 3 to 5 week gain, 5 to 10 week gain, feed consumption, and gain: feed ratio. Rat experiments were conducted for a 26 day period following which proximate analyses were made on individual rat carcasses. Feed consumption, body weight gain and gain: feed ratio and carcass characteristics were

determined. Digestibility trials were also conducted with pigs and rats.

Prior to weaning, pigs consumed very small amounts of any of the diets and there were no significant treatment differences in 3 to 5 week gain. After weaning, pigs consuming the control diet were heavier ($P<.05$) at 8 and 10 weeks, gained at a greater ($P<.05$) rate from 5 to 10 weeks and consumed greater ($P<.05$) amounts of feed. Differences between the corn and 1/2 corn: 1/2 broken rice diets for these parameters were not significantly different but gain and gain: feed ratio were lowest ($P<.05$) for broken rice. It was suggested that the cause of differences in performance was due to differences in feed consumption. In the rat experiment, performance on the broken rice and the corn diets at 20% protein was similar but at 14% dietary protein, gain and gain: feed ratio was greater ($P<.05$) on broken rice than on the other diets.

Digestibility of energy in the pig experiment was highest ($P<.05$) for broken rice but digestibility of nitrogen was low for all diets. In the rat experiments, digestible energy and nitrogen levels of all diets were greater than in the pig experiment and broken rice diets were more highly digested ($P<.05$) than other diets.

Treatment differences were minor for carcass characteristics. Rats fed 20% protein diets had lower levels of carcass dry matter, fat and energy and higher levels of ash and protein than those fed diets containing 14% protein.

It was concluded that performance on broken rice based diets should be similar to corn-based diets and that broken rice of good quality is suitable as the major energy source in pig starter diets.

ACKNOWLEDGEMENTS

Many people and institutions have co-operated in this study both in Canada and Thailand and without their support, this project could not have been completed. For their particular contributions to this study, gratitude is expressed to:

Dr. L.P. Milligan, Chairman and Professor of Animal Science, The University of Alberta, and Dr. Prateep Rachapaetayakom, Chairman and Professor of Animal Science, Kasetsart University, Bangkok placed the facilities of their respective departments at my disposal.

The National Research Council of the Government of Thailand officially sanctioned the project in Thailand and provided assistance in obtaining visas and necessary permits.

Special thanks must be expressed to the Canadian International Development Agency (CIDA) who awarded the author a scholarship under the Scholarship Program for Canadians and provided financial support for the project. The assistance of Mr. L.P. Laplante of CIDA is particularly appreciated. The National Research Council of Canada through a grant to Dr. Bowland, assisted in the support of some phases of the project.

Dr. J.P. Bowland, Professor of Animal Nutrition, University of Alberta by his patience and encouragement at all times and particularly in approving the choice of subject and editing the manuscript has greatly assisted the author.

Dr. Sucheeb Ratarasarn, Professor of Animal Science, Kasetsart University supervised the part of the study conducted in Thailand and the staff at Tabkwang Swine Breeding Station assisted in every possible way in making my stay in Thailand a memorable one.

Dr. R.T. Hardin and Mrs. Dolores K. Lam assisted in statistical analyses of the data.

Dr. J.E. Johnston, Head of Agricultural Project, Rockefeller Foundation, Bangkok provided much needed transportation in Thailand and, in addition, provided continuing encouragement and assistance.

Mr. P.J. Martin, Animal Nutritionist, Soil and Feed Testing Laboratory, Alberta Department of Agriculture conducted proximate analyses of feeds. Mr. J. McCarthy also assisted in this regard. Mrs. Jean Heard conducted amino acid analyses. Mr. P. Larson assisted with care of the animals at the University of Alberta.

The understanding and patience of my wife, Nicole, is deeply appreciated, particularly during my long absence in Thailand.

To all these people and others whom I may have inadvertently omitted, I am sincerely grateful.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

In Thailand as well as in much of South East Asia, the pig is the main meat producing animal and thus provides the people of that region with an important source of high quality protein to help balance the staple diet of rice. The typical Thai dietary regimen usually consists of a large amount of rice with a small amount of meat or vegetables. Consequently, the majority of the protein in the diet is derived from rice, which is known to be deficient in lysine particularly, and also threonine (Houston and Kohler, 1970). Although the amino acid profile of rice generally approaches the human requirements more closely than that of other cereals, Kik (1965) found that growth in rats was enhanced by including protein supplements. These findings reflect the general situation of response to protein supplementation of cereal-based diets in both animals and man. In view of the small quantities of supplement traditionally used in human diets in Thailand, the protein must therefore be of high biological value if the amino acid requirements of the people are to be met.

Not only must the protein supplement be of high nutritional value, but it is also essential that the price be within reach of the mass of the population, if widespread nutritional deficiencies, with all the attendant

sociological and political as well as physiological problems are to be avoided. In Thailand the importance of pork in the diet is such that efficiency of production becomes of paramount importance.

As in many other developing countries, lower production costs of livestock can be achieved in Thailand by increased utilization of locally available materials as feedstuffs. Such utilization results in a saving of much needed foreign exchange and may in some cases lead to the possibility of export sales. Considerable scope for expansion of the pig industry in Thailand would be possible if more locally produced feed ingredients were used, since large quantities of corn and cassava as well as some soybean meal (SBM) and fishmeal (FM) are now exported. Utilization of even a portion of these within the country and further reduction of imported products would be desirable.

The starting period represents a crucial phase of the pig's life, in that survival through this period is a good indication of survival to market weight which is a basic and certainly essential criterion in the development of a pig industry. It was thus felt that development of simplified starting rations, utilizing corn and/or broken rice and comparing these with a more complex ration containing imported dried skim milk (DSM) would provide much needed

qualitative information which would be useful in the further development of pig raising and feeding in Thailand.

LITATURE REVIEW

Rice (*Oryza sativa* L) is one of the two major cereals that provides a large part of the total nourishment of the world's population. Corn (*Zea mays*) is the most common grain fed to livestock throughout the world. In Thailand the major proportion of corn grown is the flint type (*Zea mays* indurata), the principal difference from *Zea mays* dent varieties being that it contains a harder endosperm which is more resistant to insect damage, an important feature in tropical areas.

RICE AND RICE BY-PRODUCTS

Rough rice or paddy rice consists of an edible endosperm and a heavy covering husk or hull, which constitutes 18-28% of the weight of the rice (Juliano, 1972). This hull is virtually indigestible by monogastric animals, including man and the pig (Houston, 1972) and therefore requires a considerable amount of processing in order to produce a product suitable for human consumption. A considerable amount of rice by-products thus results from the milling process. Many of these by-products have traditionally been utilized in livestock diets in rice-growing areas to some extent, but more extensive and more efficient usage would be desirable, particularly in view of

the importance of production of a readily available source of high quality protein such as pork.

Two major by-products of commercial milling are rice bran and polish. The definition of rice bran suggested by the Food and Agriculture Organization of the United Nations (FAO, 1964) is "a by-product from the milling of rice, consisting of the outer layers of the kernel with part of the germ". Similarly, polish is defined as: "the by-product from milling rice consisting of the inner bran layers of the kernel with part of the germ and a small portion of the starchy interior". In Thailand broken rice and rice bran containing varying amounts of hull, germ and polish are the main by-products and both are extensively used in traditional and modern swine diets.

Some experimental work has been done on rice bran (Houston, 1972) mostly in the United States but very little research appears to have been done on rice products which could be classified as similar to Thai broken rice. This situation arises from the fact that Thai broken rice is not a single product but is a composite of broken endosperms of polished rice, broken endosperms of brown rice (de-hulled rice prior to removing bran), rice bran, polish and germ. Since few references to this material appear in the literature, the closest approximation of the suitability of

broken rice as an ingredient in pig starters can be obtained by considering the constituent ingredients and drawing inferences about the composite material.

a) Broken rice

The end result of rice milling is the production of polished rice kernels for human food. This product is often in short supply in rice growing areas, thus it has seldom been fed to livestock. However Deobald (1972) estimated that 15% of the rice milled in the United States is broken in the normal milling process. This material is classified as brewers' rice since the brewing industry makes use of broken rice in place of other grains. This provides the major commercial outlet for broken rice in the U.S.A. (Pomeranz, 1972). Because the broken grain is worth only one-half the value of unbroken grain, the milling trade is anxious to keep breakage to a minimum. With continuing technical improvement in milling, the use of broken rice as a livestock feed will not likely expand in the U.S.A. (White, 1972). In Thailand the relative importance of the rice crop is much greater than in the United States and proportionately larger quantities of rice are milled. Consequently greater quantities of broken rice and other rice by-products are produced and made available as livestock feed, similar to the situation existing with wheat

milling by-products in North America.

Some indication of the nutritional value of broken rice can be gained by considering the data published on white and brown rice. NRC (1968) suggested a crude protein (CP) of 7.3% for white and 8.5% for brown rice with a digestible energy (DE) of 3619 and 3604 kcal/kg. for pigs. Houston and Kohler (1970) suggested C.P. levels of 5.3 - 13.4% for white rice and 5.7 - 13.5% for brown rice with variations due to variety, location and year. Juliano (1972) suggested Protein Efficiency Ratios of the following rice products: brown rice 1.73 - 1.93; milled (white) rice 1.38 - 2.56; bran 1.61 - 1.92; embryo 2.59; and polish 1.84 - 1.88. Kik (1957) observed that brown rice has a slightly lower digestibility than white rice for rats. Noland (1960) found that growing and finishing pigs gained equally well with similar feed/gain ratios when broken rice partially or completely replaced corn. Bray (1943) had previously suggested that broken rice could be considered equivalent to corn for pigs. Gains and feed conversion efficiency (FCE) were similar when rice by-products were used in replacement for corn and feed costs were generally reduced.

b) Rice bran, polish and germ

Bran accounts for 5-9% of the total weight of paddy rice. Polish, or white bran, accounts for a further 2-3% of

the weight (Houston, 1972). A general value of 10% total bran may be considered normal. Since germ and polish are often sold combined with rice bran, they will be considered in this discussion of bran.

Early work by Kik (1942) showed that protein in rice bran and polish was of good biological value when these ingredients supplied 5% of protein in the diet of rats. Also Duckworth and Massey (1946) suggested that bran and polish would be good sources of B-vitamins as well as providing proteins and energy. Noland and Scott (1963) found that rice bran could replace up to 50% of the corn in the ration but because of the high oil content in the bran, carcasses were classified as soft pork if higher levels were used. Houston (1972) showed that bran contained 14-17% oil, rice polish 10% and germ 23 percent.

The high level of oil in rice bran can cause problems in the use of this material in swine diets since a lipase in the bran can readily hydrolyze triglycerides in the oil liberating large quantities of free fatty acids which may be oxidized (Akazawa, 1972). The oil itself contains powerful natural antioxidants and in paddy rice, the lipase and oil are contained in distinct cellular structures but these are ruptured during milling, allowing an intimate mixing (Juliano, 1972). Thus, the feeding value may be lowered by

the rancidity and accompanying odour which results.

Work on rice by-products in livestock feeding is very limited, particularly on broken rice. This no doubt reflects the focus of research interest in utilization of rice as a human food and the lack of significant quantities of rice by-products being widely available as feedstuffs.

Although none of the work cited referred directly to use of rice by-products in pig starting diets, it can be surmised that, depending on levels of bran and hull included with the broken grains of brown and white rice, broken rice should be quite comparable to corn as an energy source. Increased levels of bran and particularly hull would lower the nutritive value. The expected major cause of a lowered nutritive value would be an increased fibre level which would be particularly detrimental to a young pig. Decreased DE level as a result of high fibre level impairs performance of young pigs (ARC, 1967).

CORN

The corn grown in Thailand is largely of flint (*Zea mays* indurata) genetic origin and as such may have slightly different feeding characteristics than the U.S. dent varieties more commonly reported in the literature. The values reported by the NRC (1968) indicated a minor

difference on an 'as fed' basis between flint and dent corn but this difference disappeared when expressed on a dry matter (DM) basis. This was confirmed by Dr K. Koga (Manager, Nutrition and Feed Formulation Division, Nihon Nosan Co., Yokohama, Japan - Personnal communication) who stated that Thai corn was used in formulating swine diets in Japan in the same manner as corn from the U.S.A.

Corn is the principal grain fed to livestock throughout the world and was the main energy source used in the reports reviewed in this study. Although CP is lower, DE is on the average higher than the other grains. This factor, coupled to high yield and wide adaptibility to various climatic and soil conditions accounts for its widespread use.

PROTEIN SOURCES FOR THE YOUNG PIG

In the suckled pig, the sow's milk provides a protein with a very high biological value, resulting in excellent growth and feed conversion. In fact the young pig on this diet doubles its weight in the first week of life (Lucas and Lodge, 1961). Because of high nutrient availability of milk protein, dried cow's milk or DSM has often been used in diets for young pigs. However the increasing cost of DSM has led to research to find alternative protein sources.

The initial report on a series of experiments at the

Rowett Research Institute by Smith and Lucas (1956) showed that at 8 weeks of age, pigs which had been weaned at 10 days weighed 21.2-24.1 kg. and had made larger body weight gains than suckled pigs. During the first stages up to 11.4 kg., a diet containing 41% DSM was used. In a later experiment at the same institute, Lucas et al (1959) reported that diets containing 28-30% CP based on whitefish meal resulted in reduced feed intake and a 6% decrease in gain compared with diets containing DSM. Also, growth was increased when a 20% DSM diet was fed from 4.1 to 11.8 kg. compared with a diet containing 41% DSM. It was noted however that a reduction in cost of feed resulted when the ration containing fishmeal was used.

Hays et al (1959) compared DSM and SBM in baby pig rations and found that gains and FCE were significantly improved on the DSM diet compared with the SBM diet. However, response was improved in pigs fed the SBM diet plus 0.05% D-L methionine but not to a level comparable to that of pigs fed the DSM diet.

Combs et al (1963) fed DSM, SBM and FM as the only supplemental protein sources in diets containing 17.7% CP from 2 to 8 weeks of age. Average daily gains (ADG) and feed consumption (FC) were significantly ($P<.01$) improved by feeding DSM rather than SBM or FM. In another trial SBM and

peanut meal were compared. Performance on SBM diet was significantly ($P<.01$) superior to peanut meal. Overall ranking would indicate: DSM>SBM>FM>>peanut meal (>>denotes marked difference).

Bowland (1965) showed that from 3 to 9 weeks of age a diet containing 40% DSM produced gains and FCE superior to a similar diet containing 20% DSM. However, cost of gain was markedly increased with the higher level of DSM. A diet containing no DSM was shown to be definitely inferior to one containing 40% DSM. These agree with the results of Combs et al (1963).

Meade et al (1965) did not find any response in gain and FCE to inclusion of 10% DSM in corn - SBM diets of pigs weaned at 3 weeks. However later work (Meade et al, 1969a) showed that pigs weaned at 5 weeks and fed a starter containing 10% DSM were significantly ($P<.01$) heavier at 63 days of age but were not more efficient in feed utilization than were those fed a diet without DSM.

Bayley and Carlson (1970) found that piglets gained significantly ($P<.05$) faster when a complex diet containing 10 or 15% DSM plus oat groats, rolled wheat and corn oil was fed compared with a simple corn-SBM diet.

Zimmerman (1972) reported studies with pigs 2-3 weeks

of age at weaning and found significant ($P<.01$) improvement in gain occurred when 10 or 20% DSM was added to diets containing corn, SBM and sugar in the first week. Thereafter, no significant differences were noted for the 4 week experimental period. He also noted that smaller pigs at weaning (3.0 kg.) benefitted more from DSM than those weighing 4.5 kg. It was also suggested that dried whey could improve performance over a simple corn - SBM diet but differences were not significant.

Recent work by Wahlstrom et al (1974) showed no response to inclusion of 10% DSM or 10% low-lactose whey in a corn - SBM diet fed from 3-4 weeks of age until 8-9 weeks of age. Also 5% sugar did not affect FC. Overall performance in this trial was low, thus in view of Zimmerman's (1972) suggestion of greater response in lighter pigs, perhaps it could be expected that the pigs fed DSM would have shown a greater response.

Puchal et al (1962) showed that gain, FC and plasma amino acid levels for young pigs were greatest when DSM was included as the major protein supplement in the diet followed by SBM, FM, cottonseed meal and meat meal in that order. Also, source or origin of FM may be an important consideration. Blair (1961) in Britain found whitefish meal superior to SBM as a source of protein for young pigs but

Puchal et al (1962) and Combs et al (1963) in America and presumably using Peruvian meal, found FM was inferior to SBM.

In summary, it can be concluded that performance of young pigs can be increased by the use of high quality ingredients such as DSM. However, it may be necessary to include DSM at a minimum level of 20% of the total diet in order to show a consistent response, at which point its use may be uneconomical.

PROTEIN LEVELS AND DIET COMPLEXITY

The CP requirement of the young pig cannot be considered without reference to the source of protein and the essential amino acid levels in the diet (ARC, 1967). An addition to this statement might also be made to include the other ingredients in the diet as one nutrient cannot be considered in isolation from the others.

Blair (1961) compared diets containing protein levels of 28, 23 and 18% and including various amounts of either whitefish meal or SBM for pigs from 4.5-11.4 kg. DSM was included in all diets at a level of 20%. Results showed that with diets based on whitefish meal, growth rate was improved 11% ($P<.05$) and FCE by 14% ($P<.001$) when the level of CP was increased from 18% to 23% CP. Further increasing protein

level to 28% by increasing the level of FM did not improve performance. However, when SBM was the major protein source, performance was not improved by increasing protein level above 18%. At this point, results were similar to FM diets with 18% protein. It must, however be stated that while differences were significant, they were not large. Further, there were no significant differences in growth rate and feed conversion from 11.4 to 18.2 kg nor to market weight at 90 kg.

An interesting sidelight of the above experiment was that 4 out of 5 pigs on the 28% protein diet containing SBM had to be killed because of severe illness. Autopsy revealed a severe anemia and liver degeneration with chronic ulceration of the cardiac region of the stomach. A definite cause of this problem was not found but the suggestion was entertained that the SBM was implicated since the problem did not arise in pigs on other treatments.

Earlier work by Peo et al (1957) with four levels of protein (15, 20, 25, 30%) and four levels of fat (0, 2.5, 5, 10%) showed that during the first 2 weeks on trial, pigs which had been weaned at approximately one week and weighed 2.9 kg. produced gains and FCE in a linear response to increasing protein level. Over the 4 week experimental period no advantage was noted from diets containing more

than 20% protein. No significant differences in response could be attributed specifically to fat over the 4 week period but during the first 2 weeks significantly ($P<.05$) more feed was required per unit gain as fat levels increased.

Rutledge (1961) did not find significant differences in gain when pigs were fed 16.9, 20.5, 23.0 or 27.6% protein in a ration consisting of corn, SBM, tankage and 11% DSM in all diets. FCE was also not significantly different but a trend toward improved conversion with increasing protein level was noted. These results were determined with a total of 39 pigs which had been weaned at 3 weeks and studied for 5 weeks. Variation in the experiment was such that perhaps significant differences could not be detected with the small number of experimental animals per treatment, even though actual differences were quite large.

An increase in growth rate was noted by Sewell et al (1961) when protein level was increased from 10 to 15% in purified diets for pigs weaned at 3 weeks of age with a lesser increase when protein levels were increased from 15 to 20%. FCE was improved with increasing protein level.

Meade et al (1965) did not observe any difference in gain or FCE when the protein level of simplified corn - SBM diets was varied over the 6 week experimental period of pigs

weaned at 3 weeks. Initial protein levels were 22, 20 or 18%. However, if a 16% protein level was used during the initial 4 weeks or 14% in the final 2 week period, FCE was impaired. Gain, however, was maintained at a rate similar to pigs on other diets by increased feed consumption for pigs receiving the 16% protein diet.

In other experiments in the same report (Meade et al, 1965), gain was similar when 16% protein diets were fed to pigs weaned at 3 weeks as when diets containing 18% protein were fed. FCE was significantly depressed when only 16% protein was used. Addition of 0.15% L-lysine or 0.05% D-L methionine to 16% CP diets was without effect in increasing gains but L-lysine improved FCE. Addition of both amino acids was required to improve FCE to the level of 18% CP diets but no significant effect from the amino acids was noted on gains.

Protein levels of 14, 18 and 22% in creep feeds of pigs weaned at 8 weeks were studied by Whitelaw et al (1966). No significant differences were noted in gain, FCE or carcass characteristics at 56 days. This finding must, however be interpreted with caution since the dry feed only provided a part of the total diet, the remainder being provided by the milk of the sow. Aumaitre et al (1964) found no difference in gain from creep feeds containing 13 or 18% CP and 4.5 or

3.8 Mcal. GE/kg of diet but highest efficiency of protein utilization occurred with the high energy/low protein diet.

Meade et al (1969a) showed that protein level sequence of starters with either 20 or 18% CP at 3 weeks of age did not significantly affect 63-day weight, gain or gain: feed (G:F) ratios. Diets were also modified to contain 10% DSM, 10% sugar and 3% FM at each protein level sequence. A consistent trend to greater FC, larger gains and heavier 63-day weights was noted when these complex starters were fed regardless of protein level sequence. No differences were noted in G:F ratios.

Experiments designed to study age at weaning, protein content of starter and kind of starter on performance (Meade et al, 1969b) did not demonstrate significant effects resulting from protein level (17 or 20%) of pigs weaned at 3 weeks. Pigs weaned at 8 weeks were significantly heavier than pigs weaned at 3 weeks and fed either 17 or 20% simple corn - SBM diets. Gain and G:F ratio was unaffected by treatment prior to 8 weeks but backfat thickness was significantly (P<.01) greater in carcasses from pigs weaned at 3 or 5 weeks, than from those weaned at 8 weeks. Other experiments showed that G:F ratio was greater when pigs which had been weaned at 3 weeks were fed a 20% rather than 17% protein diet. Gains were not significantly different.

In a third series of experiments, Meade et al (1969c) fed simple corn - SBM diets containing 12, 15, 18, 21, 24, and 27% protein to pigs from 5.9 to 23.5 kg. Significantly inferior (P<.01) gains and G:F ratios were noted when 12 or 15% protein levels were used compared with 18% or higher. However, no impairment of performance was apparent subsequent to 23.5 kg. and no effect of early protein levels was observed on carcass characteristics, or percentages of DM, protein or either extract in the lean tissue.

Tjong-A-Hung et al (1972) found that piglets fed simplified corn - SBM diets from 5.4 to 23.1 kg. containing 16% or 20% CP gained significantly (P<.01) slower than those fed 24% protein. Also, pigs fed 16% CP required significantly (P<.01) more feed per unit gain than pigs fed higher protein levels. Gain was not affected by sex but G:F ratio was lower in barrows. There was no evidence of carry-over effects of early protein nutrition in later stages of growth or on carcass characteristics. It was also observed that the lack of significant interactions indicated that sex and dietary protein levels acted independently on the response parameters.

Rust et al (1972) found that gains were greater when pigs were fed 20 or 22% CP diets than when fed 18% CP diets with SBM, dry roasted or extruded soybeans as protein

supplements from 3 to 10 weeks of age. Significant differences in G:F ratio were not observed. A further point of interest is that the results were consistent across the three types of soy protein sources, even though SBM was superior to the whole soybean products. Although differences were numerically small, overall performance was very good and the large number of animals used (432 in one experiment and 270 in another) enabled significant but small numerical differences to be detected.

Okai (1974) found FC and gain were significantly ($P<.05$) increased when complex rations containing purified carbohydrate sources and DSM plus dried whey were compared with wheat - barley - SBM diets for piglets from 3 to 7 weeks of age. G:F ratio was not changed by complexity of the diets.

The body of the evidence indicates that starters containing 20% CP should adequately meet the protein requirements of young pigs after 3 weeks of age. However, age at weaning influences requirements to a considerable degree. Inclusion of DSM in diets at levels of 20% or more of the diet has shown a consistent response in performance but at lower levels this effect may not be observed. More complex diets which include such ingredients as sugar, oat groats or FM may not show a response over more simplified

diets. Also, certain sources of FM may be superior to SBM for the young pig. Thus it can be concluded that age of animal, source of protein and ingredients in the diet are major variables influencing dietary protein levels required for maximum performance of weanling pigs.

AMINO ACID RELATIONSHIPS IN PIG STARTING DIETS

The recommended levels of amino acids are now reasonably well defined (N.R.C., 1973). However a number of inter-related factors appear to play important roles in influencing performance levels of young pigs. Amino acid levels and availability are only a part of a larger picture. Numerous other factors are involved but physical characteristics of the diet and type of ingredients used appear to be important considerations which may not always be fully appreciated.

The classic review by Block and Mitchell (1946) demonstrated the usefulness of amino acid analyses in predicting the nutritive value of the protein in a particular foodstuff and in formulating diets of optimum nutrient composition. Development of reliable automated equipment reducing both time and expense in conducting analyses has also greatly stimulated amino acid investigations.

The importance of availability of amino acids was recognized in early work by Ingram _et al_ (1949) who studied amino acid composition of various soybean meals (raw, solvent extracted: slightly heated, properly heated and overheated plus five kinds of expeller meal). Amino acids were determined by microbiological assay following acid or enzymatic (pancreatin) hydrolysis. Uniform amino acid content of the meals was found following acid hydrolysis but the relative amounts of amino acids in the inadequately heated meal were less when enzymatic hydrolysis was used. The quantities of amino acids released by enzymatic hydrolysis correlated well with weight gain of chicks.

Many methods of assessment of amino acid availability in a variety of feedstuffs for pigs, poultry and other animals have been proposed. A more complete discussion of amino acid availability was provided by Meade (1972) who reviewed the various methods and their application to a number of protein sources. Despite the tremendous amount of recent work, Meade (1972) concluded that: "There continues to be a need for development of a rapid method for determination of availability of amino acids..."

Lloyd _et al_ (1962) conducted experiments to study the nutritional adequacy of electronically computed least-cost diets which met the NRC (1959) recommendations of pigs

weaned at 4.5 kg. Trials were conducted from 3 to 9 weeks of age. In all cases performance was significantly ($P<.05$) greater on a control diet containing higher levels of DSM, oat groats and cane molasses than on least-cost diets. Dried brewer's yeast and FM were also used in the control diets but not in the least-cost diets. Performance only approached that of the control when the number of ingredients was increased in the least-cost formulation and certain limits placed on the amount of other ingredients. It was concluded either that:

1) "present feeding standards may not describe optimum diets for early weaned pigs.

or 2) ration nutrient source or physical form of the diet is of nutritional significance for pigs of this age.

or 3) the rations used did not provide nutrients at estimated levels."

The performance of early weaned pigs fed DSM as a major protein source is generally superior to pigs fed SBM (Hays et al, 1959, Combs et al, 1963, Bowland, 1965). Differences in feed consumption appear to account for the major portion of differences in performance in these trials with FCE of DSM diets similar or slightly improved compared to other diets. It has been suggested that the superiority of DSM compared to SBM diets was due to an inability of the young pig to digest plant proteins until 4-5 weeks of age (Catron,

1963). The capability to digest plant protein was shown to increase with age (Aumaitre, 1972).

Maner et al (1962) showed, however, that the pH remained high for 4 hours in the stomach of 4 week old pigs when isolated soy protein was fed whereas the pH returned to pre-feeding levels in 2 hours when casein was the protein source in synthetic liquid diets. However in 8 week old pigs on dry diets, the pH of the stomach contents returned to pre-feeding values within 2 hours for both casein and soy protein. It was suggested that soy protein contained a buffering agent which could maintain gastric pH at a level above that required for maximal pepsin activity. Also, rate of passage of food was faster in pigs fed soy protein than those fed casein at 4 weeks (19 vs 42 hr. respectively) but at 10 weeks, rate of passage was 45 hr. in both groups.

Although amino acid levels of pig starting diets may be similar, differences in performance commonly occur. Greater digestibility of DSM diets and perhaps a lower availability of amino acids in SBM diets may account for part of the differences when diets containing DSM and SBM are compared.

DIGESTIBILITY* OF STARTING DIETS

With the advent of early weaning, digestibility studies with young pigs have been considerably expedited and reliable estimates of the digestibility of various types of diets are now available.

Lloyd et al (1957) studied the digestibility of a complex diet consisting of 37.5% DSM, 15% oat groats, 10% wheat, 10% SBM, 10% dried brewers' yeast and 10% molasses at 3 and 7 weeks of age. Digestibility of DM, energy and CP at 3 weeks were 84.4, 85.8 and 85.3% respectively and increased to 85.9, 88.6 and 88.5 at 7 weeks. Ether extract was digested only to a limited extent, amounting to 39.0% at 3 weeks and increasing to 55.1% at 7 weeks. Digestibility of total carbohydrates was 90.1% at 3 weeks and 91.1% at 7 weeks of age.

A later study (Lloyd and Crampton, 1958) confirmed the above findings of increased digestibility with age using a similar diet. However, protein and energy digestibilities at 3 weeks were 78 and 79% respectively and at 7 weeks were 84 and 85%. Replacement of DSM with dried whey and meat meal resulted in 4-9% reduction in digestibility values.

---

*Digestibility in this review refers to apparent digestibility.

Hays *et al* (1959) found digestibility of DM in rations containing 40% DSM was 96% at 2 weeks and did not improve at 5 weeks. Digestibility of diets containing SBM as the source of protein was improved during this period and averaged 88% at 3 weeks and 92% at 5 weeks. The addition of methionine improved gains and FCE but these did not match gains and FCE of pigs fed DSM diets. By adjusting gains for difference in digestibility using covariance techniques, the gains of pigs on different diets were then found to be comparable and differences not significant.

Blair (1961) showed that apparent digestibility of DM was not affected by level of protein but was lower in diets containing SBM than in those containing whitefish meal. Digestibility of DM increased with age. Also, protein digestibility was higher in diets based on whitefish meal than SBM and no effect of age was noted.

Rutledge *et al* (1961) found that digestibility of diets containing corn, SBM, tankage, 11% DSM and 5.1% lard-lecithin increased as protein levels were increased from 16 to 28%. Also, a significant decrease in nitrogen retention was noted as protein level was decreased. The authors noted the dietary protein level required to promote satisfactory nitrogen retention was higher than that required to promote satisfactory gains. It was concluded that the pig requires

at least 20% protein of high quality in the early stages of growth following 3 week weaning.

Combs _et al_ (1963) found digestibility of DM, CP, ether extract and energy was greater when DSM was included in simple diets with a single source of protein than when SBM, FM or peanut meal was used. Digestibility of peanut meal was markedly inferior to other sources of protein. Also, digestibility increased with age and significant differences occurred between the results obtained at 5-6 weeks compared with 7-8 weeks.

Bayley and Carlson (1970) conducted experiments comparing simple and complex diets and found higher digestibilities of DM, DE, nitrogen and fat with complex diets and a trend toward increased digestibility of these parameters with age from 2 to 6 weeks.

In a comparison of simple and complex starters Okai (1974) found that digestibility of complex diets was greater than simple diets. Digestibilities of energy were 86, 86.5 and 93.2% for simple, semi-complex and complex diets. Digestible nitrogen (DN) was 87.1, 85.1 and 90.5% respectively for the three diets. It should be noted that these studies were conducted at 4-5 weeks of age with pigs which had been weaned at 3 weeks.

The fact that digestibility of DM, energy or nitrogen are not necessarily closely related to performance was observed by Bowland (1964). Digestibility of energy ranged from 86 to 95% and of nitrogen from 85 to 94% in pigs of 3 to 4 weeks of age initially and studied until 8-10 weeks. The diets varied widely in nutrient composition, DE and DN. Although statistically significant differences of digestibility were found, the differences were numerically small and could not account for a major part of the differences observed in performance. It should be kept in mind that digestibility studies are carried out over a period of a few days, whereas growth responses are measured over the whole experimental period. This may account for some of the differences in cases where digestibility trials do not correlate well with growth studies.

EFFECT OF A TROPICAL ENVIRONMENT ON PERFORMANCE OF PIGS

Data on the performance of young pigs in a tropical environment are somewhat limited; therefore, results of trials with pigs of other ages must be considered and related to the weanling pig. Also, work on the effects of high temperatures carried out in other than a tropical environment may be of value provided that appropriate recognition is made of the real differences in climate.

A series of experiments have been carried out in a psychometric chamber at the University of California, Davis over a number of years showing the effect of high temperatures on gain and FCE at different body weights. Heitman (1958) reported the results of 24 environmental trials involving 94 pigs at different body weights ranging from 45.4 kg. to 158.9 kg. and different temperatures from 4.4°C to 43.3°C. This gave a total of 367 hog-periods of observations. Each trial lasted an average of 7 days. Temperature was maintained at a pre-determined level and relative humidity (RH) was maintained at 50% with constant air movement (25 $feet^3$/minute). A three dimensional correlation surface was developed showing probable values of ADG for specific combinations of air temperatures (4.4 to 43.3°C) and body weights (90.8 - 176.4 kg.). The constant air temperatures at which daily gain was at a maximum varied from 16.1°C for 176.7 kg. pigs to 22.9°C for 90.8 kg. pigs.

Bond et al (1963) using a similar experimental method to that of Heitman (1958) tested diurnal temperature combinations of constant 21.1°, 4.4°-15.5°, 10°-32.2°, 15.5°-26.7°, 4.4°-37.8°, 26.7°-37.8° and 21.1°-32.2°C. Results showed that a combination of 10° - 32.2°C resulted in poorest gain and feed conversion and both 4.4°-37.8° and 15.5°-26.7°C produced significantly inferior ADG and FCE to constant 21.1°C, which was considered optimum under

conditions of the test.

Beckett (1965) constructed a heat loss diagram in which the heat lost by pigs was partitioned at various air and skin temperatures. It was shown that at air temperature of 26.7°C, convection and radiation accounted for the majority of heat loss but at 35°C the relative heat loss from these sources was reduced and lung heat loss accounted for more than the total of the former two combined. Also, perspiration skin loss was shown to account for an amount nearly equal to that of convection and greater than the heat loss from radiation. A 'swine effective temperature' diagram was constructed giving the effective temperature to the pig at various environmental temperatures from 20.7° to 37.8°C and RH from 0-100%. This shows that the effective temperature can be increased to a physiological stress point (evidenced by elevated respiration rate) by an increase in either temperature or humidity.

Morrison et al (1968) determined the effect of humidity on gains in pigs of 68 kg. at high temperatures. The effects of humidity were additive to those of temperature. With both increasing temperature and humidity, feed consumption and gain decreased but FCE did not change to any great extent.

The previous reports did not make any mention of the usual environmental conditions under which the animals were

kept nor of the time of year in which the trials were conducted. Although these experiments were carried out in southern California, the climate in the winter is considerably cooler than in most tropical areas. Thus the seasonal variation in climatic conditions may not make the data directly applicable to an area such as Thailand where environmental conditions are more uniformly hot and humid all year.

A later report by Morrison (1972) outlining the effect of periodic spraying to cool pigs at high air temperatures specifically mentions that the trials were carried out for two years from July to September which may more closely resemble tropical conditions at certain times. It was found that a spray application of 330 ml of water per hour per pig resulted in significant (P<.01) improvement in gain and FCE. It was concluded that the main cause of improved performance was that pigs which were sprayed continued to eat throughout the hottest part of the day when other pigs rarely ate.

Little has been published on the results of experimental work with pigs in the tropics, but Babatunde _et al_ (1972) in Nigeria fed diets with protein levels from 12 to 24% CP on a DM basis. Local ingredients were used with corn as the energy source and ground nut cake, blood meal and fish meal as protein sources. The optimum CP for pigs of

9 to 34 kg. was between 22 and 24% of DM and for fattening pigs of 41 to 82 kg. was between 18 and 21% of DM. ADG of pigs fed less than 18% CP from 9 to 34 kg. was less than 0.20 kg. compared with approximately 0.4 kg. when 20 to 24% CP was fed. Similarly FCE was greater than 4.0 when less than 18% CP was fed and varied from 3.11 to 2.59 when CP level was 20 to 24 percent.

Hutagalung and Sarait (1972) in Indonesia fed diets of 12, 16 or 20% CP to Large White pigs from 2 to 12 weeks of age. Diets consisted of local ingredients with rice bran and corn as the major sources of energy and coconut cake and fishmeal as protein sources. Pigs gained significantly (P<.01) faster and required significantly less (P<.01) feed per unit of gain when 20% CP diets were fed than when 16% or 12% CP was used. Growth and feed intake on all treatments were lower than those reported from temperate climates even when allowance was made for the low protein levels in certain diets. It was suggested that the variable quality of ingredients and the high environmental temperature may have had a depressing effect on feed consumption.

Holmes (1973) measured the performance of pigs and digestibility of diets at approximately 40 and 60 kg. liveweight. The pigs were maintained at constant temperatures of 25°C or 33-35°C. All pigs were initially

maintained at 25°C from 38 to 50 days of age and then divided into the two temperature groups and maintained on these regimes until slaughter at 70 kg. Two levels of digestible energy were given by feeding different amounts of the same ration on an increasing scale. It was found that appetite was reduced, growth was slower and fecal and body heat loss increased at the higher temperature. Also, digestibility of energy and DM was decreased, consequently energy retention was decreased by the increased energy loss at high temperature. Nitrogen retention was also decreased because of decreased feed intake and increased urinary nitrogen loss. In view of the length of time the animals were maintained at elevated temperatures, this experiment may approximate tropical conditions even though conducted in New Zealand. The results are thus of particular interest relative to the current experiment.

The effects of a tropical environment on swine reproduction and lactation have also been investigated only to a limited extent. Teague et al (1968) found a decrease in percentage of gilts pregnant 25 days post coitum following exposure to dry bulb temperatures of 26.7, 30 and 33°C at dew points ranging from 11.1 to 28.9°C. A total of 240 females were used in this study conducted in controlled environment chambers. High dry bulb temperatures also increased the rate of anestrus. A significant interaction

between dry bulb and dew point was noted for feed intake and rate of gain. Warnick _et al_ (1965) had earlier found that the percentage of gilts which ovulated without showing signs of estrus was increased when the gilts were exposed to constant 32.2°C compared with those maintained at constant 15.5° or on pasture with ample shade in Florida from July to October.

Benson and Morris (1971) conducted an experiment with rats in which pregnant females were exposed during the last 14 days of the 21 day gestation period to temperatures of 37°C for 7 hours per day. The females and pups were then maintained at 23°C during lactation. Milk production as indicated by weight gain of the litter was significantly reduced in those females exposed to the high temperature compared with control animals maintained at 23°C. Subsequent gain of the pups also maintained at 23°C following weaning was reduced in animals whose mothers were exposed to high temperatures during gestation. This experiment is particularly interesting because the pattern of temperature fluctuation approximated the tropical environment encountered in Thailand. It would be interesting to determine if the same effects occur in pigs, as a reduced milk production could account for some of the reduced performance often seen in young pigs in the tropics.

Experimental work on adaptation or acclimitization of pigs to tropical conditions is scarce but Morrison and Mount (1971) maintained pigs of 20 kg. initial weight for 3 successive periods of 4 weeks at 22°, 33° and finaly 30°C constant temperature. Body weight decreased 24 hours after the first change from 22° to 33°C. However after the second change there was a large body weight increase. After the change to 33°C, feed intake stabilized by the second day but growth rate required 7 days and water intake, respiratory rate and rectal temperature required 12 days to reach steady values. Following change from 33° to 22°C, respiratory rate and rectal temperature reached steady values in one and 12 days respectively. Rate of gain was maintained during this final period at about the same level as when animals were previously kept at 22°C. However during the period of higher temperature, gains were only about two thirds (2/3) of the other two periods. FCE was not changed but feed intake was markedly reduced at the higher temperature.

Information on the use of broken rice in pig diets is very limited. This review has therefore concentrated on broader aspects of the nutrition of the young pig, including protein sources, protein levels, amino acid relationships and digestibility of nutrients. The literature pertaining to the effect of a tropical environment on performance of swine was also investigated. Inferences were made wherever

applicable to the study herein reported.

PRELIMINARY INVESTIGATIONS

The majority of the pigs in Thailand are raised under back yard, semi-extensive conditions using traditional feeding and management systems. Most do not receive any form of protein, mineral or vitamin supplementation, thus contributing to low performance levels. The vast majority of market pigs in the country are however, crosses of native X exotic breeds. Because of the increased performance usually associated with exotic as compared with native breeds (Ratarasarn and Koshi, 1955, Rigor and Kroeske, 1972), the present day Thai market pigs may respond to improved feeding and management practices. However, the feed industry in Thailand cannot service the majority of the small-scale producers, thus any improved feeds would have to be mixed by the farmer himself with the ingredients purchased from a local source. It can therefore be appreciated that simplicity of feed formulation is of practical importance, even if a certain amount of potential performance must be sacrificed.

Traditionally, pigs in Thailand have been fed on by-products from rice-milling, notably broken rice and rice bran. Usually, varying amounts of aquatic plants (water hyacinth, algae, etc.), over-ripe or inedible fruits and vegetables, household scraps, by-products and waste products

of human food preparation are also included. Low levels of DE and CP, high levels of crude fibre and mineral and/or vitamin deficiencies would be expected in such diets, resulting in low levels of performance.

PROXIMATE ANALYSES

In order to have some idea of the range of nutrient levels in Thai feedstuffs, samples of broken rice, rice bran, corn, SBM and FM were collected by the author in Thailand in 1973. Proximate analyses of these samples are shown in Table 1.

It is apparent that considerable variability in levels of CP, crude fat, and Gross Energy (GE) may be encountered in broken rice. Although the increased GE in samples 1 and 2 would largely reflect the levels of crude fat, it was observed that the particles of broken rice were smaller in these samples with high fat levels and that they contained more germ and bran than the other samples. Since broken rice in Thailand is priced roughly according to particle size, the smallest being the cheapest, it would appear from the increased CP and GE levels, that this size would have the greatest nutritional value for livestock, particularly young pigs.

Since most of the corn grown in Thailand is of the

TABLE 1. PROXIMATE ANALYSES OF CERTAIN THAI FEEDSTUFFS

Item	Sample No.	Dry Matter (%)	Crude Protein (NX6.25) (%)	Crude Fibre (%)	Ether Extract (%)	Calcium (%)	Phosphorus (%)
Broken rice	1	88.0	12.0	1.4	6.6	.05	.55
	2	88.0	12.3	2.0	7.5	.05	.58
	3	87.2	9.2	0.9	4.9	.04	.22
	4	87.3	9.6	1.0	1.0	.05	.25
	5	88.7	9.7	0.9	3.2	.04	.42
	6	87.6	10.2	1.1	3.2	.05	.42
	7	89.0	8.9	1.6	2.2	.05	.24
	8	88.3	8.9	1.7	2.4	.05	.29
Corn	1	87.8	8.9	2.2	4.0	.05	.37
	2	89.3	9.4	2.9	4.6	.07	.27
	3	88.5	9.9	2.4	3.7	.07	.35
	4	89.7	10.4	2.7	3.7	.07	.35
	5	88.5	9.8	2.2	4.0	.05	.33
Rice bran	1	90.7	13.6	11.1	19.0	.09	1.95
	2	90.8	12.6	15.6	18.3	.06	1.95
Soybean meal, expeller extracted	1	92.1	48.3	11.8	12.0	.47	.71
	2	92.1	47.4	13.0	6.0	.46	.78
Unprocessed soybeans		93.0	42.9	19.3	18.2	.33	.61
Fishmeal		93.5	51.0	0.9	4.0	8.80	3.03

Guatamalan flint varieties and as seen in Table 1, contains more CP than is usually found in North American dent varieties (NRC, 1973), it is possible that its nutritional properties may be somewhat different from the more common dent corn.

Rice bran is the most common ingredient in traditional Thai pig diets and depending on the amount of hull, extraneous material and age of animal to which it is fed, can range from a reasonably good to a rather inferior pig feed. The CP, fat and GE levels of rice bran are higher than broken rice or corn (Table 1). However, the high fibre level would make its use in pig starting diets questionable, although performance and digestibility in relation to costs has not yet been assessed in young pigs.

It should be noted that the DM determined for SBM, unprocessed soybeans and FM are higher than normal. This is probably the result of drying during storage. Also, the FM represented a poor sample since Thai fishmeal usually contains 55-60% CP.

AMINO ACID ANALYSES

Amino acid analyses were determined on the following samples of broken rice, corn and SBM and are presented in Table 2: broken rice-#6, corn-#4, and SBM (numbers

TABLE 2. AMINO ACID ANALYSES OF SELECTED SAMPLES OF THAI BROKEN RICE, CORN AND SOYBEAN MEAL

Amino Acids	Broken Rice	Corn	Soybean Meal
<u>Essential</u>			
Arginine	.82	.47	3.27
Histidine	.25	.30	1.25
Isoleucine	.39	.33	1.89
Leucine	.76	1.09	3.18
Lysine	.40	.30	2.74
Methionine	.26	.19	.62
Phenylalanine	.51	.48	2.30
Threonine	.35	.34	1.72
Valine	.55	.45	2.09
<u>Non-essential</u>			
Alanine	.54	.70	1.88
Aspartic acid	.91	.61	5.14
Cystine	.20	.25	.93
Glutamic acid	1.71	1.74	7.76
Glycine	.42	.36	1.82
Proline	.48	.90	2.54
Serine	.48	.45	2.21
Tyrosine	.30	.29	1.41

correspond to sample numbers in Table 1). Although it was not possible to determine amino acid content of all samples, these analyses do give some indication of expected values for Thai broken rice, corn and SBM.

PERFORMANCE OF YOUNG PIGS IN THAILAND

Data on the performance of young pigs from private farms and government research stations involved in a breed multiplication program of exotic breeds have been summarized by the Livestock Development Department (1970) of the Government of Thailand. These are presented in Table 3. Data from a preliminary trial conducted by the author in Thailand investigating age of weaning are also presented in Table 3. Pigs in the latter study were from primiparous gilts and were weaned at 3, 5 and 8 weeks of age. A simple 19% CP diet consisting largely of broken rice and SBM was fed from 2 weeks of age until termination of the trial at 8 weeks.

The results show that values for the Landrace pigs weaned at 8 weeks are within normally expected ranges for gilt litters (A.R.C., 1967). Performance of Durocs appears to be less than Landrace for both weight gain of piglets and litter size. Also, under the dietary and management regimen used, early weaning was shown to have a deleterious effect. In this trial, pigs weaned at 8 weeks were significantly

TABLE 3. PERFORMANCE OF YOUNG PIGS IN THAILAND

Source of data	Breed	Age at weaning (wks)	No. of litters	Birth		3 Weeks		8 Weeks	
				Litter size	Av.wt. (kg.)	Litter size	Av.wt. (kg.)	Litter size	Av.wt. (kg.)
Livestock Development Department (1970)	Landrace	8	783	9.1	1.3	8.2	5.1	7.9	12.7
	Duroc	8	802	7.9	1.3	6.8	4.4	6.6	11.7
McKinnon and Ratarasarn (unpublished)	Landrace	3	4	9.0	1.6	7.5	5.0	6.8^{2}	$6,5^{2}$
		5	3	8.3	1.5	8.0	5.1	8.0^{1}	8.5^{1-2}
		8	4	9.0	1.4	8.7	5.0	8.7^{1}	11.3^{1}

$^{1-2}$ - means bearing same letters not significantly different at $P<.05$.

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

(P<.01) heavier and litters were significantly (P<.05) larger than those weaned at 3 weeks. Although these data were somewhat limited in scope, the two experiments do give an indication of the performance levels currently being obtained in Thailand.

Although rice by-products have been the traditional pig feedstuffs and large quantities are fed, little quantitative information is available on the use of these ingredients, particularly under the climatic conditions of Thailand. Also, in view of the possibilities for increased utilization of corn grown in Thailand, it was desirable to compare the merits of corn and broken rice in pig starting diets.

OBJECTIVES

The objectives of this study were:

1. To assess the nutritive value of broken rice and ground corn as energy sources for weanling pigs in order to develop simplified pig starting diets utilizing local ingredients available in Thailand.
2. To compare simplified starting diets based on local Thai ingredients with a complex starting diet containing imported dried skim milk.
3. To assess nutrient availability of Thai broken rice and corn using weanling rats as the test species.

EXPERIMENTAL

MATERIALS AND METHODS

PIG EXPERIMENT

1. Animals and Diets

Fifty-two litters of pigs involving a total of 380 animals in 4 breed-groups were utilized in this study conducted at Tabkwang Swine Breeding Centre, Kasetsart University, Bangkok, Thailand from June to December, 1973. Analytical work was carried out later at the Department of Animal Science, The University of Alberta, Edmonton.

Breed-groups consisted of litters from the following:

	Breed-Group
-Landrace sows X Landrace boars	Landrace
-Landrace sows X Duroc boars	Crossbred Landrace
-Landrace gilts X Duroc boars	Crossbred gilt
-Duroc sows X Duroc boars	Duroc

Gestating sows were confined in groups of 3 or 4 in concrete-floored pens in open-sided barns. Approximately five days prior to farrowing, sows were washed and moved to individual farrowing crates in a similar barn where they remained until weaning.

During gestation sows were fed at a level of 1.0% of body weight per day and gilts received 1.5 kg/day of a diet

containing 22% CP and formulated to meet N.R.C. (1968) daily requirements for protein, minerals and vitamins. A 16% CP diet was fed during lactation at a rate of 1.0 kg. on the day of farrowing and increasing to an ad libitum basis within 7-10 days. This level of feeding was continued until weaning at 5 weeks post partum. The major energy source in these rations was broken rice and the supplemental protein sources were SBM plus 3% FM.

An entire litter was used as the experimental unit with litters assigned randomly to treatment according to date of birth and breed-group. Attempts were made to reduce differences in litter size by fostering piglets from large litters with sows that had smaller litters. However, the entire swine herd at the station where this work was conducted was placed under strict quarantine in August, 1973 following a suspected outbreak of hog cholera (swine fever). Therefore it was necessary to discontinue these attempts to adjust litter size for the later half of the litters farrowed.

All males were retained intact for the duration of this experiment in order to participate in later breed evaluation studies. Also since the basic experimental unit was the litter and feed consumption was of necessity determined on a litter basis, sex was disregarded. The sex effect on

performance was tested statistically and was shown to be a minor factor.

At birth, all pigs were assigned an individual number and identified by ear notch, the navel cord tied off and the stub dipped in iodine. Canine teeth were also removed at this time. Birth weight was recorded within 24 hours and 200 mg. of injectible iron administered.[1] Body weight of individual piglets was a recorded at weekly intervals until termination of the experiment when pigs were 10 weeks of age. Suckling piglets which scoured were treated orally with 1 ml. of Neo-Terramycin[2] or Tribrissen[3] and in persistent cases 1.0 ml of penicillin-dihydrostreptomycen[4] was administered intramuscularly in combination with one of the above. Weaned piglets which scoured were treated with sulfamethazine[5] in the drinking water. All piglets were treated[6] for internal parasites at 7 weeks of age.

---

[1]Imposil 200: Iron dextran complex. Fisons Ltd., Animal Health Division, Harston, Cambridge, U.K.
[2]Neo-Terramycin. Oxytetracycline hydrochloride plus neomycin sulfate. Pfizer Agricultural Division, New York, N.Y., U.S.A.
[3]Tribrissen: Sulfadiazine - 4.55% (W/V) plus trimethaprim 0.91% (W/V). Wellcome Foundation Ltd., Berkhamstead, Herts., U.K.
[4]Combiotic: Penicillin G procaine and dihydrostreptomycin sulfate. Pfizer Agricultural Division, New York, N.Y., U.S.A.
[5]Sulmet: sulfamethazine - water soluble, oral treatment. Cyanamid International, Wayne, N.J., U.S.A.
[6]Piperazine: 0.2 g. piperazine base/kg. body wt. Cyanamid International, Wayne, N.J., U.S.A.

Dietary treatments were as follows:

- control diet consisting of 20% DSM, corn and SBM
- corn - SBM
- broken rice - SBM
- equal porportions of corn and broken rice - SBM.

These diets contained approximately 20% CP and 4000 kcal. GE/kg. and were formulated to meet N.R.C. (1968) recommended levels of minerals and vitamins. Three percent fishmeal and 0.3% synthetic D-L methionine[7] were included in all diets. Detailed formulation is shown in Table 4.

The experimental diets were introduced at 3 weeks of age and litters were maintained on the same dietary regimen through weaning until completion of the experiment. Feed was supplied ad libitum and water was available from nipple waterers. Feed consumption data were collected by weighing all feed given to the entire litter three times daily and weighing all feed refused.

Determinations of 3, 5, 8 and 10 week body weight and ADG from 3-5 weeks and 5-10 weeks were made on the basis of individual pigs within litters. Average daily feed consumption (ADF) was determined on the basis of pig-days

[7]D-L. methionine (99%). Degussa, West Germany.

TABLE 4. FORMULATION AND COMPOSITION OF PIG DIETS

	Control		Corn		Broken Rice		1/2 Corn: 1/2 Broken Rice	
Ingredient (%)								
Ground yellow corn	60.8		64.9				33.5	
Broken rice					67.9		33.5	
Soybean meal (44%)	14.4		28.8		26.2		27.4	
Dried skim milk	20.0							
Fishmeal (57%)	3.0		3.0		3.0		3.0	
Salt	0.5		0.5		0.5		0.5	
Oyster shell	0.5		0.2					
Bonemeal			0.9		1.6		1.3	
Trace mineral pre-mix*	0.3		0.3		0.3		0.3	
Vitamin premix**	0.4		0.4		0.4		0.4	
Antibiotic***	113g.		113g.		113g.		113g.	
Composition (calculated)								
Crude Protein %	20.0		20.0		20.0		20.0	
Digestible Energy kcal/kg	3482		3443		3445		3455	
Calcium %	0.70		.67		.78		.71	
Phosphorus %	0.53		.56		.55		.56	
Composition (analyzed)	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Dry Matter %	89.3	(87.4-90.7)	88.9	(86.8-90.0)	88.5	(87.2-89.5)	88.7	(87.0-89.7)
Crude Protein %	20.8	(19.1-22.1)	21.8	(20.5-23.0)	21.2	(19.3-23.2)	21.4	(20.6-22.3)
Gross Energy kcal/kg	4064	(4017-4122)	4078	(4025-4138)	4045	(3974-4248)	4041	(4010-4126)
Calcium %	.93	(.88-.99)	.93	(.81-1.07)	.89	(.85-1.13)	1.01	(.84-1.14)
Phosphorus %	.62	(.55-.69)	.62	(.55-.69)	.60	(.52-.72)	.61	(.57-.69)
Crude Fibre %	3.4	(2.4-5.3)	4.4	(2.8-5.3)	3.6	(2.3-6.5)	4.1	(2.4-5.5)

*Provided the following levels/kg. of diet: copper, 26mg.; iron, 88.0mg; manganese, 24mg.; zinc, 55mg.; iodine, 0.2mg.

**Provided the following levels/kg. of diet: vitamin A, 5000 I.U.; vitamin D, 850 I.U.; vitamin E, 15 I.U.; vitamin B-12, 22mg.; riboflavin, 11.1mg.; calcium pantothenate, 23.5mg.; niacin, 50.5 mg.; choline chloride, 55.7mg.; D-L methionine (feed grade), 3g., BHT, 100mg.

***Aureo SP 250. Pfizer Agricultural Division, New York, New York, U.S.A. A 2:2:1 mixture of chlortetracycline: sulfamethazine: procaine penicillin.

and G:F ratio was determined on the basis of the total weight gained by a litter including the gain of any pigs which died, divided by the total amount of feed consumed by the litter.

2. Digestibility Studies

Estimates of digestibility of energy and nitrogen were made at two periods with a total of 20 litters at 8-9 weeks of age during a 4-day period. Because of a lack of facilities, total fecal collection could not be made, therefore grab samples of feces were collected at 9:00 on the morning of the 4th day of the digestibility trial. Ten of the litters in the second period received feed containing 0.2% chromic oxide indicator mixed by hand in batches of 10 kg.

Feces were dried at 60°C for 72 hours in Thailand and samples of feed and feces were stored at 4°C and then air-shipped to The University of Alberta for analyses four months later. Prior to the analysis, all feed and feces samples were finely ground in a laboratory mill. Analyses of dry matter, total Kjeldahl nitrogen, fibre and fat were made according to the methods of A.O.A.C. (1965). A commercial

---

[8]Matheson Scientific, East Rutherford, N.J., U.S.A. Supplied a mixed catalyst containing HgO, K_2SO_4 and $CuSO_4$.

"Kel-Pack"[8] was used to supply the catalyst for nitrogen determination and ammonia was collected in 4% boric acid. Energy content of feeds and feces were determined with a Parr Oxygen Bomb Calorimeter.[9] Calcium and phosphorus levels were obtained with a Technicon Auto Analyzer[10] and amino acid analyses were obtained with a Type 5AH amino acid analyzer[11] following the method outlined by Orok (1973). Amino acid levels of pig diets are presented in Table 5.

Analyses for chromic oxide content of the feces to determine digestibility of pig diets were conducted according to the method of Brisson (1956). However, these analyses proved to be unreliable, consequently digestibility of diets was estimated for the 20 litters in this trial using the method of McCarthy et al (1974). The ash of both feed and feces which is insoluble after boiling in 4N-HCl for 0.5 hours is utilized as an internal indicator, giving a digestibility coefficient in much the same way as the chromic oxide method. In this study 10g. of feed and 5g. of feces was used rather than 20g. and 10g. respectively as used by McCarthy et al (1974).

---

[9]Parr Instrment Co., Moline, Illinois. Temperature changes recorded by a Brown Electronik Recorder manufactured by Honeywell Regulator Co., Philadelphia, Penn., U.S.A.
[10]Technicon Instruments Corporation; Chaucey, N.Y., U.S.A.
[11]Japan Electron Optics Co. Ltd., Tokyo, Japan.

TABLE 5. AMINO ACID COMPOSITION OF PIG DIETS (as fed)

Amino Acids (%)	Control	Corn	Broken Rice	1/2 Corn: 1/2 Broken Rice
Essential				
Arginine	1.14	1.47	1.55	1.59
Histidine	.58	.65	.56	.62
Isoleucine	.89	.95	.86	.91
Leucine	1.73	1.94	1.51	1.68
Lysine	1.25	1.27	1.19	1.29
Methionine	.66	.60	.55	.64
Phenylalanine	1.02	1.11	1.06	1.09
Threonine	.80	.88	.79	.86
Valine	1.10	1.14	1.01	1.07
Tryptophan (calculated, N.R.C., 1968)	.24	.25	.24	.25
Non-essential				
Alanine	.94	1.18	.99	1.11
Aspartic acid	1.79	2.27	2.19	2.32
Cystine	.38	.49	.43	.47
Glutamic acid	3.65	4.07	3.54	3.79
Glycine	.73	.98	.92	.99
Proline	1.56	1.52	1.04	1.23
Serine	1.00	1.13	1.02	1.08
Tyrosine	.65	.64	.62	.64

RAT EXPERIMENT

1. Animals and Diets

Twenty-four weanling rats of the Sprague-Dawley strain (Department of Animal Science, The University of Alberta) were used in two experiments of 26 days duration conducted at the University of Alberta from February to April, 1974. Four rats (2 males and 2 females) were assigned at random to each of the 3 dietary treatments shown in Table 6. In experiment 1, the diets were similar to the corn, broken rice and corn: broken rice diets for pigs with broken rice and corn from Thailand comprising the major energy sources. Dietary protein levels were 20% and 0.3% synthetic D-L methionine was added to each diet as in the pig experiment. Canadian herring meal (72% CP) and soybean meal (47% CP) were added to provide an amount of protein equivalent to that of Thai fishmeal and soybean meal in the pig diets. In experiment 2, diets were formulated to more closely match the requirements of the weanling rat (N.R.C., 1972) and contained 14% CP with the same cereal sources as experiment 1 but only soybean meal (SBM) as the supplemental protein source. The mineral - vitamin pre-mix commonly used in the rat colony at the Animal Science Department of The University of Alberta was used in both experiments.

In experiment 1 rats averaged 58.9 g. (males, 62.2; females, 55.6) at allotment and in experiment 2

TABLE 6. FORMULATION AND COMPOSITION OF RAT DIETS

	EXPERIMENT 1			EXPERIMENT 2		
	Corn	Broken Rice	1/2 Corn: 1/2 Broken Rice	Corn	Broken Rice	1/2 Corn: 1/2 Broken Rice
Ingredients (%)						
Ground yellow corn	70.26		34.79	86.79		42.56
Broken rice		68.92	34.79		83.43	42.56
Soybean meal (47%)	24.16	25.50	24.84	10.35	13.71	12.02
Herring meal (72%)	2.42	2.42	2.42			
D-L methionine (feed grade)	0.30	0.30	0.30			
Mineral-vitamin* premix	2.86	2.86	2.86	2.86	2.86	2.86
Composition (calculated)						
Crude Protein %	20	20	20	14.00	14.00	14.00
Composition (analyzed)						
Dry Matter %	91.02	88.37	88.28	88.50	87.70	88.23
Crude Protein %	21.58	20.43	20.86	14.04	14.04	14.00
Gross Energy kcal/g	4078	3868	4001	4063	3827	3945

*Provide the following levels/kg. of diet: ground limestone 0.80%; calcium phosphate, 0.50%; salt, 0.4%; cobalt, 2.8 mg.; copper, 24.6 mg.; iron, 294.1 mg.; manganese, 76.2 mg.; zinc, 88.5 mgs.; Vitamin A, 4,400 I.U.; Vitamin D, 550 I.U.; Vitamin E, 11 I.U.; riboflavin, 11.1 mg.; calcium pantothenate 22.2 mg.; niacin, 50.5 mg.; choline chloride, 55.7 mg.; folic acid, 1.65 mg.; Vitamin B-12, 19.8 mg.

the corresponding weights were 48.7 gm (males, 49.8; females 47.5).

Rats were kept in individual anti-coprophagy cages in a temperature and humidity controlled room (22°C, 45% RH). Food and water were supplied ad libitum. Cages were cleaned weekly and body weight (BW) and FC were also measured on a weekly basis. Determinations were also made of body weight gain and G:F ratio.

2. Digestibility Studies

A digestion trial involving all rats was conducted in experiment 1 from the 10-14th day when rats initially weighed an average of 114.9 gm. Because rats were considerably lighter at the start of experiment 2, the digestion trial was conducted from the 13-17th days at an average initial weight of 113.9 gm. Feed consumption was determined daily and feces were collected and stored at 4°C until the end of the collection period and then dried at 105°C for 2 hours. Digestibility coefficients were determined by the total collection method. Digestibility of energy and nitrogen was determined as described by Sibbald et al (1957).

3. Carcass analyses

At the end of the 26 day feeding period, rats were

weighed and killed with chloroform. Carcasses were then dried in a forced air oven[12] for 6 days at 60°C at which time carcass weight had stabilized at about 1 g. of weight loss per day. After equilibration to atmospheric conditions weights were recorded as air dry body weight. The whole carcasses were subsequently frozen in dry ice and ground through an 20.3 cm laboratory mill[13] using a 2mm. mesh screen.

The mill was pre-chilled prior to grinding each rat by grinding a quantity of dry ice. This prevented the fat in the carcass from melting during grinding and plugging the screen. The ground carcasses were stored in plastic bags until chemical analyses were conducted.

DM and total nitrogen in the feed and in the carcasses were determined as outlined previously for the pig diets. The GE in feed and feces were determined using a bomb calorimeter. Analyses of carcass ash and carcass fat were made according to methods of A.O.A.C. (1965).

The amount of energy stored in the entire carcass was estimated using the following equation (Orok, 1972):

GE(carcass)=GE (protein) + GE (fat)

---

[12]Style V31 - Despatch Oven Co., Minneapolis, Minnesota.
[13]Christy and Norris Ltd., Chelmsford, England.

where

GE(carcass)=Gross Energy stored in whole rat carcass

GE(protein)=Gross Energy in carcass protein

=CpXWX5.65 kcal/g.

Cp=% crude protein in individual carcass

W=DM wt. of rat (g.)

5.65=kcal/g. protein

where

GE(fat)=Gross Energy in carcass fat

GE(fat)=CfXWX9.40 kcal.

Cf=% crude fat in individual carcass

W=DM weight of rat (g.)

9.40=kcal/g. fat

STATISTICAL METHODS

Analyses of variance were computed to determine if significant differences existed. The sources of variation and traits are presented in Table 7. Rations and breeds were considered as fixed sources of variation. Notation used to indicate level of significance is: *($P<0.05$), **($P<0.01$), ***($P<0.001$). Multiple comparisons of means were made ($P<.05$) using Duncan's Multiple Range Test (Steel and Torrie, 1960) and means not significantly different bear the same superscript.

TABLE 7. SOURCES OF VARIATION AND NUMBER OF TRAITS

Species	Period or Experiment	Traits	Diet	Breed	Sex	Litters by treatment combination	Observations per treatment by sex combination
Pigs	Pre-weaning (3-5 weeks)	Performance: 3 and 5 week weight, FC, ADG	4	4		13	Note: see Appendix Table 1
	Post-weaning (5-10 weeks)	Performance: 8 and 10 week weight, ADF, ADG, G:F ratio.	4	4		13	11
		Digestibility Studies: DE, DE levels of diets, daily DE intake, DN, DN levels of diets, daily DN intake	4			6 litters for control and broken rice diets; 4 litters for corn and 1/2 corn: 1/2 broken rice diets.	
Rats	Experiments 1 and 2	Performance: FC, gain, G:F ratio	3		2		2
		Digestibility Studies: DE, DE levels of diets, DN and DN levels of diets.	3		2		2
		Carcass Analyses: DM, ash, protein and fat content of carcasses, carcass energy, energy retention in carcasses.	3		2		2

In the pig experiment there were unequal numbers of pigs per litter and litters within breed-group combinations (Appendix Table 1). Because of the unequal number, analyses of variance of the performance traits were computed using dummy variables in a multiple regression program as outlined by Searle (1971). Analyses of variance of the pig digestibility studies were computed considering only diets as a source of variation. Multi-way analyses of variance were computed for the rat experiments.

The results of the pig experiment are based on pigs which survived until 10 weeks of age. A total of 14 pigs died during the experimental period, the number being distributed across all treatments. Data for feed consumption were calculated on the basis of pig-days and average daily gains were based on the total weight gained by pigs reaching 10 weeks of age. G:F ratios were based on the total gain of a litter including gain of pigs which died divided by total feed eaten per litter. No rats died during the experimental period.

RESULTS AND DISCUSSION

The results are considered under the following categories:

a) Performance

b) Digestibilities of diets

c) Carcass characteristics (rats only).

Results of pig experiments are discussed in terms of pre-weaning as well as post-weaning performance, since diets were introduced at 3 weeks of age and weaning took place at 5 weeks with the same diets fed until 10 weeks. Where appropriate, results are also discussed in terms of breed groups.

Little information was available in the literature comparing broken rice and corn for pigs but where possible the results of the present study are compared to other work.

PIG EXPERIMENT

A. Pre-weaning

Body weight at 3 and 5 weeks, 3 to 5 week feed consumption and 3 to 5 week ADG are presented in Table 8. At 5 weeks no significant effects of treatments were observed on weight, feed consumption or gain. There was, however a significant ($P<.05$) breed effect on weights at 3 and 5

TABLE 8. PRE-WEANING PERFORMANCE OF PIGS

	DIETS				BREED-GROUP			
	Control	Corn	Broken Rice	1/2 Corn: 1/2 Broken rice	Landrace	Crossbred Landrace	Crossbred gilt	Duroc
No. of Litters	13	13	13	13	16	12	12	12
Weight/pig								
3 weeks kg.	4.64	4.74	4.92	4.80	5.11^{1}	4.88^{1}	4.96^{1}	4.15^{2}
5 weeks kg.	7.44	7.41	7.70	7.36	7.98^{1}	7.69^{1}	7.73^{1}	6.50^{2}
Feed Consumption /litter 3-5 weeks kg.	1.89	1.50	2.06	1.29	1.48	1.76	1.58	0.77
Average Daily Gain/pig 3-5 weeks kg.	0.20	0.19	0.20	0.18	0.21	0.20	0.20	0.17

weeks, with the Duroc piglets weighing less than others. On the other hand, the 3 to 5 week ADG was not significantly different, indicating that although Duroc pigs were lighter at the beginning of the experiment, they gained during the 2-week period at a rate comparable to the other pigs. While breed effects may be significant for certain factors, they are not central to the discussion and are not therefore discussed in detail.

The most notable effect observed was the small amount of all rations consumed following introduction of the diets at 3 weeks of age. In light of the quantities of nutrients required to gain at a maximum rate, a creep feed is usually provided to supplement the declining milk production of the sow in the later stages of lactation (Lucas and Lodge, 1961). Also, if the sow's milk production is somewhat deficient, piglets will usually increase consumption of creep feed. Lodge (1959) found that litters of sows receiving low energy intake and producing less milk than sows on high energy intake did in fact increase creep consumption to compensate for reduced nutrient supply from the sow. The principal deficiency of the suckling pig at 3-5 weeks is digestible energy (A.R.C., 1967) and it is usually accepted that since the pig tends to eat to meet it's energy requirement, increasing quantities of creep feed will be consumed to make up this deficiency. Numerous factors enter

into consumption of creep feed including palatability and freshness of feed, milk production of the sow and the management system under which the animals are kept. Whether the assumption could be made that the piglets in this experiment were not eating the feed because they were receiving sufficient nutrients from the sow is difficult to say. They were, however, frequently observed eating the sow's ration while ignoring the creep feed a few feet away but the amount of sow feed actually consumed could not be determined.

The problem of low creep feed consumption at various weaning ages up to 8 weeks was not limited to this trial, but in the experience of the author and colleagues in Thailand, has been a common one at a number of stations. Inclusion of a wide variety of feed ingredients to the creep feed diet as well as sweetening and flavouring agents has not shown any response under practical conditions.

Okai (1974) showed a similar effect of very low creep feed consumption. Amounts of creep feed consumed from 10 to 20 days of age while suckling were 12.5, 21.7 and 71.3 g. for simple semi-complex and complex diets. However it was concluded from estimates of milk production and growth rate of the piglets that sufficient nutrients were received in milk to permit maximum growth.

The body weights in the present experiment observed at 5 weeks, live weight gains and feed consumption from 3 to 5 weeks are less than could be expected in a temperate climate (A.R.C., 1967), but the effects of a humid tropical climate on these parameters has not been definitely established. Such a climate may have some effect on milk production and because of the close correlation between milk production of the sow and body weight gain of the litter (Lucas and Lodge, 1961; Lewis and Speer, 1973), could have contributed to the low gains. Benson and Morris (1971) showed that milk production in rats was impaired following exposure to a high temperature (37°C) for 7 hours per day during the last 14 days of pregnancy. This regimen approximated the diurnal tropical temperature variation but whether a similar effect occurs in the sow is not known. Also, it is difficult to determine whether the work cited represented a heat stress response or the response of an animal adapted to such conditions. Morrison and Mount (1971) showed that body temperature and respiration rate in growing pigs had reached steady values, indicative of physiological adaptation, within a week of change in environmental temperature from 22 to 33°C and from 33° to 20°C. A similar response may occur in the lactating sow. Since the sows in this experiment were the second generation of these lines of pigs raised in Thailand, it could be reasonably expected that they would be

adapted to the climate to the greatest physiological extent possible.

B. POST WEANING

1. Performance

Results of performance from 5 to 10 weeks of all pigs are presented in Table 9 and include 8 and 10 week body weight, ADF, ADG and G:F ratio.

a) 8 and 10 week body weight

At 8 weeks a significant ($P<.05$) difference was apparent in body weight of pigs on the control diet containing 20% dried skim milk (DSM), compared with the other animals. No significant differences were noted between animals fed the other three diets.

At 10 weeks a response similar to that at 8 weeks was observed, with pigs receiving the control diet weighing significantly ($P<.05$) more than the other pigs. Although differences between the other diets were not significant, the pigs fed the broken rice diet weighed 1.74 and 1.40 kg. less than pigs on the corn and corn: broken rice diets respectively.

b) Average daily feed consumption

Data were collected on a litter basis but ADF was determined on the basis of pig-days to enable comparisons to

TABLE 9 POST-WEANING PERFORMANCE OF PIGS

		DIETS				BREED-GROUPS			
		Control	Corn	Broken Rice	1/2 Corn: 1/2 Broken Rice	Landrace	Crossbred Landrace	Crossbred gilt	Duroc
No. of Litters		13	13	13	13	16	12	12	12
No. of Pigs*		87	102	94	97	134	99	69	78
Weight									
8 weeks	kg.	14.30^{1}	12.55^{2}	12.01^{2}	11.80^{2}	13.43^{1}	13.69^{1}	12.55^{1-2}	11.00^{2}
10 weeks	kg.	21.64^{1}	18.55^{2}	16.81^{2}	18.21^{2}	20.04^{1}	20.32^{1}	18.12^{1-2}	16.73^{2}
Average Daily Feed Consumption	kg.	$.84^{1}$	$.65^{2}$	$.63^{2}$	$.64^{2}$	$.70^{2}$	$.80^{1}$	$.65^{2}$	$.61^{2}$
Average Daily Gain	kg.	$.41^{1}$	$.32^{2}$	$.26^{3}$	$.31^{2}$	$.34^{2}$	$.36^{1}$	$.30^{2-3}$	$.29^{3}$
Gain: Feed		$.49^{1}$	$.50^{1}$	$.41^{2}$	$.47^{1}$	$.50^{1}$	$.45^{2}$	$.44^{2}$	$.48^{1}$

*No. of pigs on which statistical analysis conducted = No. pigs alive at 10 weeks.

be made between diets even though there were different numbers of pigs on each of the treatments (Table 9). It was shown that pigs consumed significantly ($P<.05$) more of the control than the other diets, which were consumed at a similar rate over the 5 week experimental period.

c) Average daily gain

ADG reflects both initial body weights and feed consumption in that gains of pigs on the control diet are significantly ($P<.05$) greater than other pigs. Also, pigs on corn and 1/2 corn; 1/2 broken rice diets gained significantly more than those fed broken rice. This indicates that the apparent differences in body weights at 10 weeks were probably real differences even though not statistically significant.

d) Gain: feed ratio

Significantly ($P<.05$) less gain was produced by pigs on the broken rice diet per unit of feed consumed than on other diets. Differences in G:F ratio between the other diets were non-significant.

e) Breed effects

Breed differences were apparent in the parameters measured with poorest responses from Duroc pigs, with the exception of G:F ratio, where a response similar to purebred Landrace was noted. This appears to be a continuation of the

situation encountered prior to weaning. As was noted in the discussion of the pre-weaning period, Durocs weighed less at the beginning of the trial at 3 weeks of age but gained at a rate comparable to other pigs up to weaning at 5 weeks.

Significant interactions between treatments and breeds occurred for 8 and 10 week weight and ADG. These interactions presented no consistent pattern and are not considered further. Interactions at each age were not the same and there is no evidence to suggest that the breed groups used in this study would respond differently to dietary treatments.

Significant ($P<.05$) differences between the control diet and the other diets were observed in both 8 and 10 week body weight, feed consumption and 5-10 week gain. Feed conversion was not significantly different. Thus, a markedly increased feed consumption resulted in clearly significant differences in body weights and gains although the diet was utilized at an efficiency level similar to the corn and corn: broken rice diets. The fact that this difference was apparent at 8 weeks after only 3 weeks post-weaning and that the control diet was consumed in much larger quantities compared with other diets indicates that it was clearly superior. The major difference between this diet and the corn diet, in particular, was the DSM.

Bowland (1965) found that 20% DSM in starting diets of pigs weaned at 3 weeks resulted in superior gains and feed conversion from 3-8 weeks and minor differences in feed conversion. Meade _et al_ (1965), however, did not detect any significant effects from inclusion of 10% DSM in pig starters. Later work (Meade _et al_, 1969a) showed a significant improvement in feed consumption and gains from inclusion of 10% DSM but no improvement in G:F ratio.

The results of the present study agree with these findings in that feed consumption and gain were increased by the inclusion of 20% DSM, but G:F ratio was not greatly affected. The generalized effects of inclusion of DSM can be exemplified by the findings of Puchal _et al_ (1962) who found body weight gains were ranked according to source of supplementary protein: DSM>SBM>FM>> cottonseed meal > meat meal.

2. Digestibility Studies

The results of the digestibility studies which were conducted are shown in Table 10. Data are presented on DE, DE of the diets, daily DE intake, DN, DN of the diets and daily DN intake. Significant differences ($P<.05$) were noted for DE but not for DN. From these values, the DE and DN of the diets were calculated but no significant differences

TABLE 10. ENERGY AND NITROGEN DIGESTIBILITY OF PIG DIETS

		Control	Corn	Broken Rice	Corn: Broken Rice
No. of Litters		6	4	6	4
Energy					
% Digestible (DE)		81.1^{2}	82.1^{2}	85.7^{1}	81.9^{2}
DE of diet (as fed)	kcal./kg.	3312	3348	3428	3335
Average daily DE intake	kcal.	2783^{1}	2176^{2}	2160^{2}	2134^{2}
Nitrogen					
% Digestible (DN)		75.1	76.3	73.9	72.1
DN of diet (as fed)	g./kg.	24.9	26.3	24.6	24.7
Average daily intake	g.	21.9^{1}	17.1^{2}	15.5^{3}	15.8^{3}

*Based on grab samples from whole litters at 8-9 weeks of age.

were found. These results should be interpreted with caution since they were, of necessity, based on fecal grab samples taken at one time only, one hour after the morning feeding. Moore (1957) found that fecal excretion of chromic oxide, CP, crude fibre and chromic oxide - free ash depended on length of time between feeds and on the number of daily feeds. The method use in this experiment to estimate digestibility (4N-Hcl insoluble ash) includes any chromic oxide added to the feed and thus is present in the feces. The chromic oxide added to the feed could be a source of error, particularly since the chromic oxide method of estimating digestibility was shown to be unreliable in this study. McCarthy <u>et al</u> (1974) found very close agreement between the 4N-Hcl method and total fecal collection for DM, CP and DE of diets of early-weaned pigs of 4.5 weeks of age.

a) <u>Digestible energy</u>

The digestion coefficient for DE was significantly ($P<.05$) greater for the broken rice diet (85.7%) than for other diets (avg 81.7%). This finding is some what surprising in view of the reduced performance (ADF and G:F ratio) of pigs on the broken rice diet. A reduced G:F ratio is inconsistent with increased digestibility. Whether the increased digestibility is an anomaly produced either by sampling error or a result of increased solubility of rice

dry matter as compared with corn, which may have occurred during digestion with 4N-HCl, cannot be determined. Because of differences in excretion patterns, it is possible that an artificially high digestibility was measured which did not occur consistently.

The NRC (1973) recommends 3500 kcal. DE/kg. in pig starting diets but none of the rations used in this experiment provided the level recommended. However, considering the GE levels of the diets which were approximately 4050 kcal/kg., and a more usual digestibility of 85-90% (Hays et al, 1957; Bayley and Carlson, 1970; Okai, 1974) for rations such as these, it can be seen that the energy requirement would have been met under usual conditions. In addition, O'Grady and Bowland (1972) found that the optimum DE level with early weaned pigs fed barley or wheat diets from 3-8 weeks was 3200 kcal./kg. in one experiment and 3400 kcal./kg. in another. Therefore it appears unlikely that DE levels of the diets were a limiting factor in performance.

The difference in performance between pigs on the control diet and the other three diets can be clearly appreciated from the DE intake data. The difference in daily feed consumption of the control diet reflected in daily DE intake counteracts any small differences in energy

digestibilities in favor of other diets. The pigs fed the control diet consumed 22.5% more DE than the average of the other three diets and pigs at 10 weeks weighed an average of 17.5% more.

b) Digestible nitrogen

No significant differences in DN are apparent in the present experiment.

Digestibility of nitrogen or protein is often slightly less than digestibility of energy (Rutledge et al, 1957, Okai, 1974). The DN coefficient determined in this study (72.3%) was however, markedly lower than digestibility of energy (84.3%). The reason for this difference is unknown.

The DN levels in the diets reflected the digestibilities and therefore do not show any major differences. The DN levels are somewhat less than would be calculated from the N.R.C values for crude protein.

The daily intake of DN closely approximated the situation of daily DE and also reflects both a relative and an overall low level of protein. The crude protein levels of the diets are known to be sufficient to produce adequate performance, but with the low digestibility of nitrogen in this experiment, a protein as well as an energy deficiency

may have resulted when considered in relation to the amount of food consumed. This could account for at least a portion of the overall low performance. However, performance exceded that found in the preliminary studies with young pigs in Thailand. The results of the digestibility studies are consistent with the performance figures.

The possibility exists that a residual amount of soybean trypsin inhibitor (SBTI) could have remained in the SBM after crushing which could have affected nitrogen digestibility. Facilities for processing were somewhat limited and the soybeans may not have been heated sufficiently to inactivate the trypsin inhibitor. This could lower performance and digestibility.

A quick field test was devised to give an indication of residual trypsin inhibitor activity after processing (Dr L.G. Young, University of Guelph - Personnal Communication). A description of the method is provided in the appendix. It was possible to estimate that the meal used contained 0-10% of the original SBTI activity of the raw beans.

Although active trypsin inhibitor can definitely interfere with protein metabolism, particularly of sulfur amino acids (Leiner, 1973), it would be expected in this experiment that the digestibility of the diet containing DSM would be greater than other diets since only 14% SBM was

used in the control diet. Double that level of SBM was used in the other diets yet digestibility of nitrogen was not different between diets. A further factor mitigating against an involvement of active SBTI is the high level of supplemental methionine added to all diets. Leiner (1973) and Yen et al (1974) suggested that supplemental methionine can alleviate to some extent the effects of SBTI.

RAT EXPERIMENTS

The two experiments with rats were run consecutively, essentially as separate experiments. Data for both experiments were later combined in an overall analysis to provide a quantitative assessment of the differences between the trials and in so doing, provide information which would not otherwise be available on the nutritive value of Thai corn and broken rice.

The diets (Table 6) fed in experiment 1 were similar to the pig diets fed in Thailand, in that the same sources of energy and similar levels of protein and supplemental methionine were used. De-hulled SBM obtained in Canada and Canadian herring meal were substituted for Thai SBM and FM respectively. The amounts of these included in the diets were calculated to supply the same quantities of protein as the SBM and FM used in the pig diets.

In experiment 2, the protein level was reduced to 14%, a level which more closely approximated the amino acid requirement of the growing rat (N.R.C., 1972). The purpose of this was to determine if there were real differences between corn and broken rice which had been masked by the high protein levels in the diets used in the previous trial. The basal energy sources were corn, broken rice or 1/2 corn: 1/2 broken rice as in experiment 1.

The 20% protein level in experiment 1 quantitatively provided enough amino acids relative to the rat's requirement to negate any qualitative differences in nutritive value between corn and broken rice. It was felt that such qualitative differences, if they existed, would be more apparent at lower protein values.

SBM was the only source of supplemental protein in experiment 2. The 14% protein level provided an excess of lysine relative to recommended requirements (N.R.C., 1972), thus, performance should not have been limited by this nutrient which is known to be the most limiting amino acid in both rice and corn (Kik, 1965; Houston and Kohler, 1970). Marginal deficiencies of methionine and cystine may have occurred when compared with N.R.C. (1972) recommendations for the rat.

For purposes of comparison with other experiments, it would have been of interest to conduct this trial on the basis of Protein Efficiency Ratio. However, if this had been done, SBM could not have been used as the protein source. Protein Efficiency Ratio is usually determined at a 10% protein level using egg albumin or casein as the protein source. At this level SBM does not provide enough lysine or methionine and cystine to meet the requirement of the growing rat. It would not then have been possible to make direct comparisons with the diets used in experiment 1 or with the pig diets.

The combined analysis of experiment 1 and experiment 2 facilates comparison between the two experiments in order to delineate the possible differences between experiments. It was possible to make this comparison because both numbers of rats and sexes were balanced on each treatment in both experiments. This comparison cannot be represented as a true factorial design since herring meal and supplementary methionine were included in experiment 1 and omitted in experiment 2. Thus it cannot be stated that differences are due to protein level alone. This analysis does however make it possible to state with a reasonable degree of precision that a given response is or is not different in the two trials. Despite these limitations, useful information is provided to illustrate certain trends in the response which

occurred in this experiment.

Several constraints were imposed in the rat experiments. It would have been desirable to use the same sources of protein as well as energy as were used in the pig experiment in Thailand, but it was not possible to import sufficient extra quantities of Thai corn and broken rice as well as Thai SBM and FM which would have been needed in order to fully investigate the effects of protein sources. Similarly, it would have been desirable to investigate the response of rats fed the control diet used for pigs in order to determine whether the increased performance in pigs was a consistent effect. However the same constraints existed in terms of importing sufficient quantities of DSM as well of even greater quantities of Thai SBM, FM, corn and broken rice. Consistent with the objectives of this experiment, which was to evaluate the nutritive value of Thai corn and broken rice in order to develop simplified pig starters which could have wide application in Thailand, it was decided to investigate only those factors which were directly related to the objectives. Because the function of the diet containing DSM in the pig experiment was to serve as a control, it was not included in the rat experiment.

Similarly, it would have been desirable to use a greater number rats per treatment as the increased number of

animals would have allowed a greater degree of experimental precision. However, the constraints previously mentioned regarding the quantities of ingredients which could be imported from Thailand precluded greater numbers of experimental animals.

1. Performance

Results of performance in the rat experiment are presented in a similar manner to results in the pig experiment and include feed consumption, body weight gain and gain: feed ratio for the 26-day experimental period. Discussion of the results also includes differences between the two trials based on the combined analysis of experiments 1 and 2. Degrees of freedom and means squares are presented in the analysis of variance tables in the Appendix.

a) Feed consumption

There were no significant differences in FC between treatments in experiment 1 (Table 11). Feed consumption differences were also small in the pig experiment but the broken rice diet was consumed by pigs in lesser quantities than the other diets.

The FC in experiment 2 was similar to experiment 1. There were no significant differences in amounts of the

TABLE 11. FEED CONSUMPTION BODY WEIGHT GAIN, and GAIN:FEED RATIO PER RAT 0-26 DAYS

Diet	Feed Consumption (g.)		Gain (g.)		Gain:Feed Ratio	
	Exp't 1	Exp't 2	Exp't 1	Exp't 2	Exp't 1	Exp't 2
Corn	377	406	140	126[3]	.37	.31[2]
Broken Rice	391	412	144	137[1]	.36	.33[1]
1/2Corn:1/2Broken rice	391	417	142	132[2]	.36	.31[2]
<u>Sex</u>						
Males	423	451	177	150	.42	.33
Females	349***	371***	109***	113***	.31***	.30***
Grand mean	386	412***	143	132***	.36	.32***

diets consumed. It should be noted that three of the four rats fed the corn diet in experiment 2 were observed in poor physical condition during the first week on trial and lost weight for some days. Analysis of variance of weekly feed consumption showed significantly ($P<.05$) reduced FC of the corn diet for the first week and no significant differences thereafter. The cause of this feed intake reduction could not be determined.

A significant ($P<.001$) sex effect was observed in both trials, with males consuming considerably more feed than females. A significant ($P<.05$) sex X treatment X trial interaction also occurred when the trials were combined. This is likely related to the problems of rats fed the corn diet. Greater reduction of feed intake occurred in males than in females.

b) Gain

Data of body weight gain is presented in Table 11. In experiment 1 no significant differences were observed. Pigs on the other hand, which were fed the broken rice diet, gained at a significantly ($P<.05$) slower rate than those on the other treatments.

Significant ($P<.05$) differences in gain between all three diets occurred in experiment 2. Animals fed the broken rice diet gained a greater amount than other animals and

those on the 1/2 corn: 1/2 broken rice diet gained more than those on the corn diet. There were, however significant ($P<.05$) sex by treatment interactions: males on the corn diet gained considerably less than on other treatments while females on this diet gained at a similar rate to other animals on other diets. This interaction no doubt reflects the initial feed intake problems with the rats fed the corn diet. Analysis of variance of weekly gains showed that rats on the corn diet gained significantly ($P<.05$) less in the first week than other rats but thereafter no significant differences were evident.

When both trials were combined a significant difference ($P<.001$) between trials was noted but it is difficult to determine the influence on the overall results of the poor response on the corn diet in the first week. Significant interactions of sex X treatment ($P<.05$) and sex X trial ($P<.001$) occurred but the treatment X trial interaction was non-significant. There was, however, a significant sex X treatment X trial effect. This indicates that the response to treatments in both experiments was similar although the absolute values differ, as can be seen in the grand means of both trials.

Rats fed diets containing 20% protein plus herring meal and 0.3% methionine (experiment 1) gained significantly more

than those on 14% SBM-corn or rice diets (experiment 2) when the two experiments were combined. Perhaps certain essential amino acid requirements were not being met by the lower protein diets, since levels of other nutrients were similar in both diets.

c) Gain: Feed ratio

Results of G:F ratio are presented in Table 11.

In experiment 1, no significant differences were observed which reflects the findings observed for FC and gain. In experiment 2, significantly ($P<.05$) more gain was produced per unit of feed consumed for the broken rice diet than for the other two diets, which did not differ from each other. Although differences for G:F ratio were significant in the pig study, the order was reversed to that found in this study.

The overall results of FC, gain and G:F ratio emphasize the inter-related nature of the performance data, similar to that observed in the pig experiment. Significant differences were evident only for the body weight gain in experiment 2 and it was shown that this probably resulted from an unexplainable loss of weight and a reduction in feed consumption during the first week on experiment by rats consuming the corn diet. An important aspect of the rat data is the fact that performance on the broken rice-based diet

is as good as that on the corn based diet. In the pig experiment, however, the broken rice diet produced significantly ($P<.05$) inferior gains and gain: feed ratio. However, the differences were not large with either species, suggesting that similar results can be expected from practical diets based on either cereal source.

2. Digestibility Studies

Data of DE, DE levels of the diets (DE/g), DN and DN levels of the diets (DN/g) are presented in Table 12.

Rats fed the corn diet in experiment 2 had recovered from their initial setback at the time this digestibility trial commenced and gains and feed intake were not different at the time of the digestibility studies from those of the rats fed the other diets.

a) Digestible energy

DE in experiment 1 was significantly ($P<.05$) greater for the broken rice diet than other diets, which was also the case in the pig experiment. Also, the order of magnitude of the increased DE coefficient for the broken rice diet is about the same in both this trial and in the pig experiment. However, the absolute digestibility coefficient for all diets indicated by the grand mean is higher for rats: 88.6%

TABLE 12. ENERGY AND NITROGEN DIGESTIBILITY OF RAT DIETS

Diet	DE				DN			
	% digestible		level in diet		% digestible		level in diet	
	Exp't 1	Exp't 2	Exp't 1	Exp't 2	Exp't 1	Exp't 2	Exp't 1	Exp't 2
			kcal./g.	kcal./g.			mg./g.	mg./g.
Corn	85.9^{3}	87.2^{3}	3.498^{3}	3.544	84.2^{2}	83.2	28.94	18.8
Broken Rice	91.1^{1}	93.2^{1}	3.524^{2}	3.570	87.5^{1}	87.4	28.58	19.8
1/2Corn:1/2Broken rice	88.7^{2}	90.7^{2}	3.550^{1}	3.577	84.8^{2}	85.7	28.57	19.2
<u>Sex</u>								
Males	88.7	90.3	3.530	3.563	85.6	85.4	28.76	19.3
Females	88.4	90.4	3.517	3.565	85.4	85.5	28.75	19.3
Grand mean	88.6	90.4***	3.524	3.564**	85.5	85.4	28.70	19.3***

vs 81.3% for pigs. The diet containing 1/2 corn: 1/2 broken rice was intermediate in digestibility to the broken rice or corn diets, being significantly ($P<0.05$) different from both. Thus, DE of diets could be ranked: broken rice > 1/2 corn: 1/2 broken rice > corn.

In experiment 2 the same ranking of diets was observed as in experiment 1. The over-all digestibility was improved compared with experiment 1 and the grand mean for DE was 90.4% in experiment 2 vs 88.6% in experiment 1. The difference in digestibility between the 2 experiments was significant ($P<.001$).

There were no differences in DE coefficients associated with sex. This is contrary to findings of O'Grady and Bowland (1972) who observed marked differences between male and female rats in digestion of energy.

DE levels per gram of diet in experiment 1 was lowest for the corn diets and highest for the 1/2 corn: 1/2 broken rice with the broken rice falling between the other two. In the pig experiments there were no differences between diets for this parameter. The broken rice used in the rat diets was a sample from one particular lot of rice while the pig diets were mixed several times and different lots of broken rice were used each time. This was necessary because it is not possible to store rice by-products for any length of

time if the rice oil is not extracted (Houston, 1972). The oil itself contains strong antioxidants but when the cellular structures which normally retain the oil in the whole grain are ruptured in milling, rapid oxidation of the oil can occur and rancidity result.

In experiment 2 the same relative DE levels were found as in experiment 1 but differences between diets were not significant.

The combined analysis shows a rather small absolute difference between the diets, even though differences were significant ($P<.01$).

b) Digestible nitrogen

In experiment 1 DN was significantly ($P<.05$) higher in the broken rice diet than in the other two diets, which were similar. No significant differences between diets were observed in experiment 2. When the two experiments were combined, the same situation was observed as in experiment 1. Sex differences for DN were also non-significant.

With the rats, overall digestibilities were somewhat less for nitrogen than energy (grand mean 85.4% (DN) vs 89.6% (DE)). There was a marked difference in DN between the

rats and the pigs. The grand mean of the pig experiment is only 72.3% vs 85.5% for rats, a difference of considerable magnitude. This effect was not observed in other work involving both rats and pigs (Likuski et al, 1961) and since it was similar across all treatments may be related to either the environmental conditions in Thailand, the animals used in this study, or the quality of the protein supplements.

In experiment 1 no significant differences were observed for DN levels in the diets and all values lie within a narrow range. The values for all diets are considerably increased compared with the results of the pig digestibility studies. This reflects the greater digestibility of all diets by rats.

In experiment 2 the DN level of the corn diet was significantly ($P<.05$) less than the broken rice diet but not significantly different from the 1/2 corn: 1/2 broken rice diet.

The combined analysis did not show any significant differences within trials, indicating nitrogen was in fact digested at a similar rate in both experiments but the marked difference between experiments reflects the different original protein levels: 20% in experiment 1 and 14% in experiment 2.

The overall results indicate that minor differences may occur but, by and large, the diets were utilized at essentially equivalent rates.

The large differences due to sex in the parameters of performance which were investigated were not apparent in the digestibility studies as the diets were digested at essentially similar rates by both sexes. Thus, it can be concluded that the greater gains made by males were due to increased food consumption and a more efficient conversion of feed into body tissue.

A number of points are evident in comparison of the rat digestibility trials to similar studies in pigs. Although Likuski _et al_ (1961) found many similarities in parameters of digestible energy and digestible nitrogen between pigs and rats and postulated that rats could serve as effective models for pig experiments, inter-species comparisons such as these must be approached with caution.

The most important difference in terms of the focus of this study, is the markedly improved digestion of the broken rice diets by rats. In the rat study, the DE, DN and also performance were greater in the broken rice diets than in the corn diets. In the pigs, digestibility of energy of the broken rice diet appeared greater but digestibility of

nitrogen was the same as other diets. The reason for the improved utilization of broken rice diets in rats may or may not be a species difference but is difficult to explain in view of the similarity of digestible energy and nitrogen levels, amino acid levels, vitamin and mineral supplementation within the rat and pig experiments respectively.

The major difference between the two species is the marked improvement in digestibility of both DE and DN by rats. In the discussion of DN, it was pointed out that the protein sources used in the rat trials were different from those used in the pig study. The possibility exists that the SBM and herring meal used in the rat studies were of higher nutritive value than that used for pigs, although the amounts used would have supplied similar levels of protein. The digestibility and availability of nutrients could, however, have been greater than in the pig diets. This factor cannot be ruled out, particularly in view of the markedly increased digestibilities of nitrogen by rats. A further factor could have been the difference in relative physiological age between the pigs and the rats. The experimental period of 4 weeks after weaning for rats represents a much longer period of physiological development than 5 weeks in pigs.

3. Carcass Analyses

Data on dry matter, ash, protein and fat in the rat carcasses are presented in Table 13.

a) Dry matter

DM of carcasses dried to a constant body weight at 60°C was determined by further drying at 100°C for 24 hours. Therefore, the DM values presented in Table 13 indicate the actual percentage DM of the rat bodies at the time of death.

No significant differences in DM were noted in experiment 1, although a significant ($P<.01$) sex effect was noted. Males contained a significantly ($P<.05$) lower percentage DM than females. This indicates that the increased body weight gain in males was in fact partly water. This result is consistent with findings of Orok (1972).

Although carcasses of females contained a higher percentage DM than males in experiment 2, the apparent differences between sexes were not significant. Also there were no significant differences due to treatments.

When the two experiments were analyzed together, a significant ($P<0.001$) effect was noted. The grand mean for DM in experiment 1 was 36.3% and 43.3% in experiment 2.

TABLE 13. ANALYSIS OF DRIED RAT CARCASSES

Diet	Dry Matter (%)		Ash (%)		Protein (%)		Fat (%)	
	Exp't 1	Exp't 2	Exp't 1	Exp't 2	Exp't 1	Exp't 2	Exp't 1	Exp't 2
Corn	35.9	43.9	10.7	9.2	61.3	52.2[2]	27.1	35.9
Broken Rice	36.3	42.9	10.5	8.9	60.8	55.3[1]	27.8	35.1
1/2Corn:1/2Broken rice	36.6	42.6	11.1	8.9	65.2	56.5[1]	25.4	32.6
Sex								
Males	34.7	42.6	10.0	8.6	62.4	54.3	27.4	35.2
Females	37.8**	43.7	11.4**	9.4*	62.4	55.1	26.2	33.8
Grand mean	36.3	43.1***	10.7	9.0**	62.4	54.7***	20.8	34.5***

These differences occurred even though rats in experiment 1 gained more than those in experiment 2. However, Peterson *et al* (1954) found that carcass moisture showed an inverse relationship to carcass fat in chicks. Fat analyses of carcasses in the present study showed a higher level of fat in experiment 2, and will be discussed at greater length in the section dealing with carcass fat. The results of the present experiment are thus in agreement with the work of Peterson *et al* (1954).

Calculation of DM levels on a fat-free basis resulted in a marked reduction of the differences, which were then no longer significant, between the trials.

b) *Ash*

The percentage of ash in the carcasses on a DM basis followed a similar pattern to DM content but differences due to treatments were non-significant in both experiments. Percentage ash of female carcasses was significantly ($P<.01$) greater than males in experiment 1 and the difference was significant at the 5% level in experiment 2.

A significant ($P<.001$) effect of experiments was observed in the combined analyses. Ash level was 10.8% for experiment 1 and 9.0% in experiment 2 (grand mean). This reflects the greater fat level of rats in experiment 2 since

when the ash levels were calculated on a fat-free basis, the differences between experiments were not significant.

c) Protein in carcass

No significant differences were observed in the percentage protein of DM of the carcasses of rats in experiment 1. In experiment 2 however, the protein level in the carcass of rats fed the 1/2 corn: 1/2 broken rice was significantly ($P<.05$) greater than those fed the corn diet. Carcasses of rats fed the broken rice diet also contained a higher level of protein than those on the corn diet.

When the two trials were combined, protein level of rats fed the 1/2 corn: 1/2 broken rice diet was significantly ($P<.05$) greater than the other two diets. There was a significant ($P<.001$) effect due to trials - the grand mean of carcass protein was 62.4% in experiment 1 and 54.7% in experiment 2. This is to be expected since the dietary protein level was much higher in experiment 1 than in experiment 2. (20 vs 14%) and likely of better quality since 2.8% herring meal was used as well as 0.3% methionine.

d) Fat in carcass

No significant differences in treatments or sex were noted in fat content of the carcasses on either trial.

However, rats on experiment 2 were significantly fatter than those in experiment 1 at the end of the experimental period. The grand means were 26.8% and 34.5% for experiment 1 and 2 respectively. The energy levels on both diets were similar but the rats on experiment 1 received a greater amount of protein relative to energy and thus a narrower energy: protein ratio than those in experiment 1. These rats in experiment 1 gained more and assimilated a greater percentage of body tissue as protein. On the other hand, rats with a wider dietary energy: protein ratio gained less weight but accumulated more fat relative to protein.

e) Energy retention in dried rat carcass

Data on Carcass Energy, Carcass Energy per gram of body weight (DM basis) and Carcass Energy/Total Energy Digested are given in Table 14. In order to determine the amount of carcass energy actually gained during the experimental period, the total calculated energy contained in carcass protein and carcass fat of the entire animal was corrected for body protein and fat of rats at the beginning of the trial using the values determined by Orok (1972). Analyses of variance was also performed on the total energy of the carcass not corrected for initial energy. Results of this analysis agreed with the analysis of Corrected Carcass Energy and therefore only the latter is reported.

i) corrected carcass energy (kcal)

Treatment effects were non-significant in experiment 1 but significant (P<.001) sex effects were found. The same situation occurred in experiment 2 in which carcasses of males contained significantly (P<.001) more energy than females. Rat carcasses in experiment 1 contained significantly (P<.001) less energy than those in experiment 2. This no doubt reflects the increased fatness of the carcasses noted previously in experiment 2.

ii) carcass energy per gram body weight (DM)

The results in Table 14 show that no significant differences due to treatments or sex occurred in energy contained in the rat carcasses when carcass energy was expressed on a per unit body weight basis. Differences within experiments were not significant but there was a significant (P<.001) difference between trials. However, the difference was numerically small and the Grand Mean of experiment 1 was 6.0 and of experiment 2 was 6.3 kcal. per gram of body weight expressed on a dry matter basis. This indicates that the previous differences between sexes shown for carcass energy were in fact largely due to differences in body weight.

TABLE 14. ENERGY RETENTION IN DRIED RAT CARCASSES

Diets	Carcass Energy (kcal.)		Carcass Energy per Gram Body Weight (DM)		Carcass Energy/ Total Energy Digested (X100=%)	
	Exp't 1	Exp't 2	Exp't 1	Exp't 2	Exp't 1	Exp't 2
Corn	360	400	6.0	6.3	27.0	27.8
Broken Rice	379	427	6.0	6.4	27.3	29.0
1/2Corn:1/2Broken rice	378	395	6.1	6.3	26.9	26.3
<u>Sex</u>						
Males	450	460	6.1	6.4	30.1	28.6
Females	294**	355***	6.0	6.3	24.0***	26.8
Grand Mean	372	407***	6.0	6.3***	27.0	27.7

iii) <u>carcass energy (kcal.)/total energy digested (X 100 = %)</u>

The actual retention in the carcass of energy digested was not significantly different between treatments in experiment 1, but a significant ($P<.001$) sex effect was found; i.e. males retained 30.1% of the energy digested while females retained only 24.0%. In experiment 2, at a lower protein level there were no significant effects on the above parameters due to either treatments or sex.

In the combined analysis, treatment effects were not significant but sex effects were significant ($P<.05$), with greater energy retention by males than by females. A significant ($P<.001$) sex x trial interaction occurred: males in experiment 1 retained significantly ($P<.001$) more energy in the carcass than females in that experiment but males retained only slightly more than females in experiment 2. Difference between trials was not found to be significant. This indicates that the energy digested was utilized at a similar rate in both trials. It must be noted that carcass analyses were carried out on the entire animal, including viscera and contents. The ingesta would contribute a source of error to the determinations but should not change the relative values.

In summary, the rat experiments substantiate the

results with the pig experiments. Although significant differences for all parameters were not the same for both species, the differences were not large and thus show that similar levels of performance can be expected from broken rice and corn-based diets. In fact, the results suggest that broken rice may be superior to corn as a source of energy for the growing rat.

GENERAL DISCUSSION AND SUMMARY

An experiment was conducted at the Tabkwang Swine Breeding Centre, Kasetsart University, Bangkok, Thailand with young pigs from June to December, 1973. Two further experiments were carried out with rats at the Animal Science Department, The University of Alberta, Edmonton. The primary purpose of these studies was to assess the nutritive value of broken rice and ground corn as energy sources for weanling pigs in order to develop simplified pig starter diets utilizing local ingredients available in Thailand. Three of the dietary treatments in the pig experiment involved a comparison of broken rice, ground corn or 1/2 broken rice: 1/2 ground corn as the basal energy sources. A more complex diet containing 20% dried skim milk and ground corn was used as a control.

The experiment with pigs showed that starting diets were not consumed by pigs in appreciable quantities during the pre-weaning phase from 3 to 5 weeks of age. In view of the nutrients required by the suckling pig to gain at maximum rate at this stage of growth (A.R.C., 1967), and the expected body weights at 5 weeks of age, gains from 3 to 5 weeks were somewhat less than could be expected in a temperate climate. No significant differences in feed consumption were apparent between treatments at this period,

even though the DSM diet was consumed in significantly ($P<.05$) greater quantities than other diets in the period after weaning from 5 to 10 weeks. These finding suggest a need for further work in Thailand to determine the factors responsible for low creep feed consumption with particular reference to the climatic conditions. Estimates could be made of the energy requirement of suckling piglets in relation to the hot, humid environment and results compared with findings from temperature climates to determine if environment or other factors are responsible for this problem.

In the post-weaning period, average daily feed consumption and average daily gains were significantly ($P<.05$) greater on the control diet containing 20% DSM. However, in consideration of the objectives of this trial which were in part to develop pig starters using local ingredients available to the majority of the pig farmers in Thailand, the use of DSM cannot be recommended. The main reason for not recommending the use of this ingredient is cost. The increased performance of weanling pigs could not possibly pay for the cost of DSM at current market prices. Indeed, previous work reported in the literature on the inclusion of DSM in pig starter diets was conducted when large surplus world stocks were available and it was a glut on the market. With a world-wide decline in productive milk

cow numbers and the predicted continued short supply and increasing price of milk in the foreseeable future, it is doubtful if the use of DSM can be justified in swine rations. This is especially so in a protein-short area such as the whole of South East Asia.

The other three diets which contained corn, broken rice or 1/2 corn: 1/2 broken rice as major energy sources were utilized in a similar manner to each other with respect to feed consumption, gain and gain: feed ratios. Although gain and gain: feed ratios were significantly ($P<.05$) less for broken rice than for other diets in the pig experiment, differences were not large. Differences in feed consumption appear to account for the major part of the differences observed in performance.

Performance of rats on diets containing the same energy sources used in pig experiment did not differ markedly. However, unlike the pig experiment, performance of rats fed the broken rice diet was greater than those fed the corn diet. Significant ($P<.001$) differences between the trials demonstrated that performance was improved when a more complex 20% rather a simplified 14% protein diet was fed. Significant ($P<.001$) sex differences showed that performance response in males was greater than in females.

With pigs, digestibility of energy was greater for the

broken rice diet than other diets, but digestibility of nitrogen did not differ between diets. With rats, digestibility of all diets was considerably better than with pigs. Digestible energy of these diets was estimated with pigs to be 3312, 3348, 3428 and 3524 kcal./kg. for the control, corn, broken rice and 1/2 corn: 1/2 broken rice diets respectively. Estimates of digestibility with rats was 3498, 3524 and 3550 kcal./kg. for the corn, broken rice and 1/2 corn: 1/2 broken rice.

Results of the carcass analyses conducted with rats reflected both the nutrient levels of the diets fed and the performance levels. Dry matter and fat content were significantly ($P<.001$) greater in rats fed a 14% protein diet but protein levels and ash were significantly increased when 20% protein was fed. Also, energy content of the carcass and carcass energy per gram of body weight were significantly greater at the lower protein level, but no significant differences were observed in energy retention.

Although differences did occur for certain parameters between pigs and rats, the actual differences, with the exception of digestibility of nitrogen in the pig experiment, were not large. These results indicate general agreement that corn and broken rice were utilized in a similar manner. The further studies on the rat carcasses did

not indicate any differences in utilization of broken rice or corn.

The preliminary studies, however, showed that broken rice is a variable product with the amount of included hull and bran dependent upon many factors. Under practical conditions of feed formulation in rice growing areas, a simple visual appraisal of the amount of hull and extraneous material and the particle size should give the experienced farmer a good indication of the suitability of a sample of broken rice for pig starting diets. In more sophisticated applications, the fibre level should similarly indicate the suitability of a sample of broken rice. The present experiment demonstrated that broken rice of good quality as the major energy source should result in performance and digestibility similar to corn-based diets.

BIBLIOGRAPHY

Agricultural Research Council. 1967. The Nutrient Requirements of Farm Livestock. No. 3, Pigs: Technical Reviews and Summaries. London.

Akajawa, T. 1972. Enzymes of rice. In Rice: Chemistry and Technology. p. 75-95. D.F. Houston (ed.) Am. Assoc. Cereal Chem. Inc. St. Paul, Minn.

Albrecht, W.J., Mustakas, G.C., McGhee, J.E. 1966. Rate studies on atmospheric steaming and immersion cooking of soybeans. Cereal Chem. 43:400-407.

Association of official Agricultural Chemists. 1965. Official Methods of Analysis. (10th ed.) Washington, D.C.

Aumaitre, A., Jouandet, C., Salmon-Legagneur, E. 1964. Cited in: The Nutrient Requirements of Farm Livestock, No. 3, Pigs: Technical reviews and Summaries. p. 105. Agricultural Research Council. London.

Aumaitre, A. 1972. Development of enzyme activity in the digestive tract of the suckling pig: nutritional significance and implications for weaning. World Rev. An. Prod. VIII:3; 54-68.

Babatunde, G.M., Olomu, M.J., Oyenuga, V.A. 1972. Determination of the optimum crude protein requirement of pigs in a typical environment. Anim. Prod. 14: 57-67.

Bayley, H.S., Carlson, W.E. 1970. Comparisons of simple and complex diets for baby pigs: effects of form of feed and glucose addition. J. Anim. Sci. 30: 394-401.

Beckett, F.E. 1965. Effective temperature for evaluating or designing hog environments. Trans. Am. Soc. Agric. Eng. 8: 163-166.

Benson, G.K., Morris, L.E. 1971. Foetal growth and lactation in rats exposed to high temperatures during pregnancy. J. Reprod. Fert. 27: 369-385.

Blair, R. 1961. The early weaning of pigs. VII. The effect of level and source of protein in the diet of pigs weaned at 10lb. liveweight on subsequent performance and carcass quality. J. Agric. Sci. 57: 373-380.

Block, R.J., Mitchell, H.H. 1946. The correlation of amino acid composition of proteins with their nutritive value. Nutr. Abstr. and Rev. 16(2): 249-278.

Bond, T.E., Kelly, C.F. Heitman, H. Jr. 1963. Effect of diurnal temperature on heat loss and well being of swine. Trans. Am. Soc. Ag. Eng. 6: 132-135.

Bowland, J.P. 1964. The relationship of energy and protein in the diet on growth and energy efficiency of young pigs. Proc. Seminaire International Organize Par l' Institute National de la Recherche Agronomique. Paris. p. 143-145.

Bowland, J.P. 1965. Pre-starters and starters for pigs. 44th Ann. Feeders' Day Report, Dept. of Animal Science, Univ. of Alberta, Edmonton.

Bray, C.I. 1943. Rice and rice by-products for fattening swine. Agricultural Experiment Sta. Bull 368. Louisiana State University, Baton Rouge.

Brisson, G.J. 1956. On the routine determination of chromic oxide in feces. Can. J. Anim. Sci. 36: 210-212.

Catron, D.V. 1963. Factors influencing the nutritional requirements of swine. p. 48-49. In Bridging the Gap in Nutrition. R.H. Thayer (ed.) Midwest Feed Manufacturers Assoc., 934 Wyandotte, Kansas City 5, Mo.

Combs, G.E., Osegueda, F.L., Wallace, H.D., Ammerman, C.B. Digestibility of rations containing different sources of supplementary protein by young pigs. J. Anim. Sci. 22: 396-398.

Deobald, H.J. 1972. Rice flours. In Rice: Chemistry and Technology. p. 264-271. D.F. Houston (ed.). Am. Assoc. Cereal Chem. Inc. St. Paul, Minn.

Duckworth, J., Massey, J. 1946. The preparation of refined rice bran. Trop. Agric. (Trinidad) 23:25-28.

Food and Agriculture Organization of the United Nations, 1964. Rice bran: utilization and trade. FAO Monthly Bull. Agr. Econ. and Statistics. 13(1): 9-14.

Hays, V.W., Speer, V.C., Hartman, P.A., Catron, D.V. 1959. The effect of age and supplemental amino acids on the utilization of milk and soya protein by the young pig. J. Nutr. 69: 179-184.

Heitman, H. Jr., Kelly, C.F., Bond, T.E. 1958. Ambient air temperature and weight gain. J. Anim. Sci. 17: 62-67.

Holmes, C.W. 1973. The energy and protein metabolism of pigs growing at a high ambient temperature. Anim. Prod. 16: 117-133.

Houston, D.F., Kohler, G.O. 1970. Nutritional properties of rice. National Acadamy of Sciences. Washington, D.C.

Houston, D.F. 1972. Rice bran and polish. In Rice: Chemistry and Technology. p. 272-300. Am. Assoc. Cereal Chem. Inc. St. Paul, Minn.

Hutagalung, R.I., Sirait, R.C.H. 1972. Effect of dietary protein level of tropical feedstuffs on performance of growing swine. Malaysian Agriculturalist. 11: 39-44.

Ingram, G.R., Riesen, W.H., Cravens, W.W., Elvehjem, C.A. 1949. Evaluating soybean oil meal protein for chick growth by enzymatic release of amino acids. Poul. Sci. 28: 898-902.

Juliano, B.O. 1972. The rice caryopsis and its composition. In Rice: Chemistry and Technology. p. 16-74. D.H. Houston (ed.) Am. Assoc. Cereal Chem. Inc., St. Paul, Minn.

Kik, M.C. 1942. Nutritive value of rice and its by-products. Univ. Arkansas (Fayetteville) Agric. Expt. Sta. Bull. 416.

Kik, M.C. 1957. The nutritive value of rice and its by products. Univ. Arkansas (Fayetteville) Agric. Expt. Sta. Bull. 589.

Kik, M.C. 1965. Nutritional improvement of rice diets and effects of rice on nutritive value of other feedstuffs. Univ. Arkansas (Fayettiville) Agr. Expt. Sta. Bull. 698.

Leiner, I.E. 1973. Toxic factors associated with legume proteins. Ind. J. Nutr. Dietet. 10: 303-322.

Lewis, A.J. and Speer, V.C. 1973. Lysine requirement of the lactating sow. J. Anim. Sci. 37: 104-110.

Likuski, H.J., Bowland, J.P., Berg, R.T. 1961. Energy digestibility and nitrogen retention by pigs and rats fed diets containing non-nutritive dilutents and varying protein level. Can. J. Anim. Sci. 41: 89-101.

Livestock Development Department. 1970. [Report of Pig Breeding Centres. Small Animal Section, Division of Animal Husbandry, Livestock Development Department, Bangkok, Thailand.]

Lloyd, L.E. Crampton, E.V., MacKay, V.C. 1957. The digestibility of ration nutrients by three vs. seven week old pigs. J. Anim. Sci. 16: 383-388.

Lloyd, L.E., Crampton, E.W. 1958. Replacement of skim-milk powder in the baby pig ration by a mixture of whey powder and meat meal. Can. J. Anim. Sci. 28: 65-72.

Lloyd, L.E., Crampton, E.W., Costain, R.A., Mowat, D.A. 1962. Use of electronically computed least-cost rations in testing the adequacy of the feeding standard for early weaned pigs. J. Anim. Sci. 21: 467&472.

Lodge, G.A. 1959. The energy requirements of lactating sows and the influence of level of food intake upon milk production and reproductive performance. J. Agric. Sci. 53: 177-191.

Lucas, I.A.M., Calder, A.F.C., Smith, H. 1959. The early weaning of pigs. IV. Comparisons of level of antibiotic and sources of protein in diets for pigs weaned at 9 lb. liveweight. J. Agric. Sci. 53: 125-129.

Lucas, I.A.M., Lodge, G.A. 1961. The nutrition of the young pig - a review. Tech. Communication No. 22. Commonwealth Bureau of Animal Nutrition, Rowett Institute, Bucksburn, Aberdeen, Scotland.

Maner, J.H., Pond, W.G., Loosli, J.K., Lowrey, R.S. 1962. Effect of isolated soybean protein and casein on the gastric pH and rate of passage of food residues in baby pigs. J. Anim. Sci. 21: 49-52.

McCarthy, J.F., Aherne, F.X., Okai, D.B. 1974. Use of HCL insoluble ash as an index material for determining apparent digestibility with pigs. Can. J. Anim. Sci. 54: 107-109.

Meade, R.J., Typo, J.T., Tumbleson, M.E., Goihl, J.H., Von der Mehden, H. 1965. Effects of protein source and level and lysine and methionine supplementation on rate and efficiency of gain of pigs weaned at an early age. J. Anim. Sci. 24: 626-632.

Meade, R.J., Rust, J.W., Miller, K.P., Hanke, H.E., Grant, R.S., Vermedahl, L.D., Wass, D.F., Hanson, L.E. 1969a. Effects of protein level sequence and kind of starter on rate and efficiency of gain of growing swine and on carcass characteristics. J. Anim. Sci. 29: 303-308.

Meade, R.J., Dukelow, W.R., Grant, R.S., Miller, K.P., Hanke, H.E. Hanson, L.E., Vermedahl, L.D., Wass, D.F. 1969b. Influence of age at weaning and kind and protein content of starter on rate and efficiency of gain of growing swine and carcass characteristics. J. Anim. Sci. 29: 309-319.

Meade, R.J., Vermedahl, L.D., Rust, J.W., Wass, D.F. 1969c. Effects of protein content of the diet of the young pig on rate and efficiency of gain during early development and subsequent to 23.5 kg. and carcass characteristics and composition of lean tissue. J. Anim. Sci. 28: 473-477.

Meade, R.J. 1972. Biological availability of amino acids. J. Anim. Sci. 35: 712-723.

Moore, J.H. 1957. Diurnal variation in the composition of the faeces of pigs on diets containing chromium oxide. Brit. J. Nutr. 11: 273-288.

Morrison, S.R., Bond, T.E., Heitman, H. Jr. 1968. Effect of humidity on swine at high temperature. Trans Am. Soc. Ag. Eng. 11: 526-528.

Morrison, S.R., Mount, L.E. 1971. Adaptation of growing pigs to changes in environmental temperatures. Anim. Prod. 13: 51-57.

Morrison, S.R., Heitman, H. Jr., Givins, R.L., Bond, T.E. 1972. Sprinkler use for swine cooling. Trop. Agric. (Trinidad). 49: 31-35.

National Acadamy of Sciences - National Research Council. 1959. Nutrient requirements of domestic animals. No. 2. Nutrient requirements of swine. pub. 648. Washington, D.C.

National Acadamy of Sciences - National Research Council. 1968. Nutrient requirements of domestic animals. No. 2. Nutrient requirements of swine. pub. 1599 (6th rev. ed.). Washington, D.C.

National Academy of Sciences - National Research Council 1972. Nutrient requirement of laboratory animals. pub. 10 (2nd rev. ed.). Washington, D.C.

National Academy of Sciences - National Research Council. 1973. Nutrient requirements of domestic animals. No. 2 Nutrient requirements of swine. (7th rev. ed.). Washington, D.C.

Noland, R.C. 1960. Feeding value of milo, barley, rice and oats for swine. Arkansas Farm Res. 9: 30-38.

Noland, P.R., Scott, K.W. 1963. Substituting various grains and rice milling by-products for corn in rations for growing-finishing swine. Univ. Arkansas (Fayetteville) Agr. Expt. Sta. Bull. 668.

O'Grady, J.F. and Bowland, J.P. 1972. Response of early weaned pigs to diets of different digestible energy concentrations and the effects of cereal source and added molasses on performance. Can. J. Anim. Sci. 52: 87-96.

Okai, D.B. 1974. Effects of diet complexity on feed intake and performance of piglets and effects of creep intake and composition on starter intake and baby pig performance. Masters' Thesis, Dept. Animal Science, Univ. of Alberta, Edmonton.

Orok, E.J. 1972. Evaluation of Nigerian feedstuffs. Masters' Thesis, Dept. Animal Science, Univ. of Alberta, Edmonton.

Orok, E.J. 1974. Comparison of peanut meal, rapeseed meal and soybean meal as protein supplements for pigs and laboratory rats. Ph.D. Thesis, Dept. Animal Science, Univ. of Alberta, Edmonton.

Peo, E.R. Jr., Ashton, G.C., Speer, V.C., Catron, D.V. 1957. Protein and fat requirement of baby pigs. J. Anim. Sci. 16: 885-891.

Peterson, D.W., Grau, C.R. and Peek, N.F. 1954. Growth and food consumption in relation to dietary levels of protein and fibrous bulk. J. Nutr. 52: 241-257.

Pomeranz, Y. 1972. Rice in brewing. In Rice: Chemistry and Technology. p. 428-448. D.F. Houston (ed.). Am. Assoc. of Cereal Chem. Inc., St. Paul, Minn.

Puchal, F., Hays, V.W., Speer, V.C., Jones, J.D. 1962. The free blood plasma amino acids of swine as related to the source of dietary protein. J. Nutr. 76: 11-16.

Ratarasarn, S., Koshi, J. 1956. Swine improvement project at Kasetsart University. Kasetsart J. 5: 140-145.

Rigor, E.M., Kroeske, D. 1972. Indigenous and exotic pig breeds in the tropics. World Anim. Rev. 4: 20-24.

Rust, J.W., Meade, R.J., Hanson, L.E. 1972. Influence of level of dietary protein and source of supplemental soybean protein on rate and efficiency of gain of pigs weaned at an early age. J. Anim. Sci. 963-966.

Rutledge, E.A., Hanson, L.E., Meade, R.J. 1961. Protein requirement of suckling age pigs. J. Anim. Sci. 20: 142-147.

Searle, S.R. 1971. Linear Models. John Wiley and Sons. New York

Sewell, R.F., Thomas, M.C., Price, D. 1951. Protein-energy relationships in the rations of early weaned pigs. J. Anim. Sci. 20: 820-823.

Sibbald, I.E., Bowland, J.P., Roblee, A.R., Berg, R.T. 1957. Apparent digestible energy and nitrogen in the food of the weanling rat. Influence on food composition, nitrogen retention and carcass composition. J. Nutr. 61: 71-86.

Smith, H., Lucas, I.A.M. 1956. The early weaning of pigs. I. The effect upon growth of variations in the protein, fat, sucrose, antibiotic, vitamin and mineral contents of diets for pigs of 8-25 lb. liveweight and a comparison of wet and dry feeding. J. Agric. Sci. 48: 220-235.

Steel, R.G.D., Torrie, J.H. 1960. Principles and Procedures of Statistics with Special Reference to the Biological Sciences. McGraw-Hill Book Co. Inc., Toronto.

Teague, H.S., Roller, W.L., Grifo, A.P. 1968. Influence of high temperature and humidity on reproductive performance of swine. J. Anim. Sci. 27: 408-411.

Tjong-A-Hung, A.R., Hanson, L.E., Rust, J.W., Meade, R.J. 1972. Effects of protein level sequence and sex on rate and efficiency of gain of growing swine and on carcass characteristics, including composition of lean tissue. J. Anim. Sci. 35: 760-766.

Wahlstrom, R.C., Hauser, L.A., Libal, G.W. 1974. Effects of low lactose whey, skim milk and sugar on diet palatability and performance of early weaned pigs. J. Anim. Sci. 38: 1267-1271.

Warnick, A.C., Wallace, H.D., Palmer, A.Z., Sosa, E., Duerre, D.J., Caldwell, V.E. 1965. Effect of temperature on early embroy survival in gilts. J. Anim. Sci. 24: 89-92.

White, G.C. Jr. 1972. Conventional rice milling in the United States. p. 188-197. In Rice: Chemistry and Technology. D.F. Houston (ed.) Am. Assoc. Cereal Chem. Inc., St. Paul, Minn.

Whitelaw, A.W.W., Elsley, F.W.H., Jones, A.S., Boyne, A.W. 1966. The effect of protein level in creep feed on the growth rate and body composition of suckling pigs. J. Agric. Sci. 66: 203-209.

Yen, J.T., Hymowitz, T., Jensen, A.H. 1974. Effects of soybean of different trypsin-inhibitor activities on performance of growing swine. J. Anim. Sci. 38:304-309.

Zimmerman, D.R. 1972. Practical pig starters. Iowa State University of Science and Technology. Co-operative extension service. Ames, Iowa.

APPENDIX

A quick field test to determine the presence of soybean trypsin inhibitor activity.

A finely ground sample (1g.) of soybean meal was placed in a test tube 1cm. in diameter and 0.2g. of urea crystals added. The tube was filled one-half full with distilled water, shaken thoroughly, a red litmus was placed on top and the tube warmed by placing in the sun. The time required for sufficient ammonia to be evolved to turn the litmus blue was recorded and compared with a similar test on the raw soybeans being processed into the meal which was sampled.

This test is based on the fact that soybeans contain an active urease (Albrecht _et al_, 1966), capable of hydrolizing urea to produce ammonia. Albrecht _et al_, (1966) showed that a decrease in soybean urease activity was paralled by a decrease in soybean trypsin activity. Therefore, the urease activity measured by this test should reflect the activity of the trypsin inhibitor remaining in the meal after processing.

APPENDIX TABLE 1. NUMBER OF PIGS PER LITTER OF EACH DIET X BREED-GROUP COMBINATION

Breed-group	Diets			
	Control	Corn	Broken rice	1/2corn: 1/2broken rice
Landrace	7,7,9,8	10,7,7,9	10,6,7,7	9,13,7,11
Crossbred Landrace	8,6,6	10,9,9	7,12,9	8,8,7
Crossbred gilt	7,4,5	9,3,9	5,8,3	11,2,3
Duroc	7,8,5	6,6,8	6,8,6	7,6,5

APPENDIX TABLE 2. MEAN SQUARES: PIG EXPERIMENT

Source of Variation	df.	Body Weight				Gain		ADF	G:F ratio
		3wk	5wk	8wk	10wk	3-5wk	5-10wk		
Diets (D)	3	2.083	3.592	99.123	363.01	.0084	.3117	.1255	.0193
Breed-group (B)	3	15.511	36.388	125.537	250.36	.0262	.1039	.0805	.0078
DB	9	3.949	12.176	63.984	111.284	.01755	.0450	.0331	.0619
Litters/DB*	36	4.199	10.490	28.023	48.214	.0117	.0203	.0163	.0041
Pigs/litters/DB	328	0.936	2.444	6.560	13.131	.0029	.0048		
Total	379								

*Indicates error term.

APPENDIX TABLE 3. MEAN SQUARES: RAT EXPERIMENT 1

Source of Variation	df.	Performance FC	Performance Gain	Performance G:F ratio	Digestibility % DE	Digestibility DE in diet	Digestibility % DN	Digestibility DN in diet
Diets (D)	2	272.06	6.7558	.00015	27.558	2698.89	11.988	.1782
Sex (S)	1	16733.	13974.	.03381	.3960	436.81	0.2523	.0303
DS	2	73.260	2.2676	.000009	.10926	250.33	0.4753	.0528
Rat/SD	6	57.698	41.176	.00012	.14306	193.95	1.0956	.11935
Total	11							

Carcass Characteristics DM	Ash	Protein	Fat	Energy	Energy / Body Wt.	Energy / Total Energy Digested
0.5091	.0334	23.865	6.0801	503.08	.0044	.1323
29.957	5.8940	.0019	4.6625	73402	.04220	114.64
.0138	.0052	1.4651	1.1156	6.6831	.0023	.1626
1.3468	.2192	7.0817	6.9125	569.89	.0207	2.3998

APPENDIX TABLE 4. MEAN SQUARES: RAT EXPERIMENT 2

Source of Variation	df.	Performance FC	Gain	G:F ratio	Digestibility % DE	DE in diet	% DN	DN in diet
Diets (D)	2	124.36	124.36	.00058	36.030	12.347	17.963	1.07217
Sex (S)	1	19344.	3960.3	.00195	.0331	.0128	.0085	.00037
DS	2	1459.7	242.72	.00012	3.7639	56.263	7.4873	.3862
Rats/SD	6	323.23	6.9599	.00009	.8592	14.525	3.7016	.18955
Total	11							

		Carcass Characteristics DM	Ash	Protein	Fat	Energy	Energy / Body Wt.	Energy / Total Energy Digested
		1.9260	.1161	20.453	12.391	1213.0	.0297	7.2970
		3.6190	2.1421	2.0667	6.0067	33123.	.0221	8.9960
		0.2641	.0559	.5465	.1958	1234.8	.0013	0.8047
		1.0199	.3131	3.4687	8.1689	615.25	.0298	1.8802

[illegible]

APPENDIX TABLE 5. MEAN SQUARES: COMBINED RAT EXPERIMENTS

Source of Variation	df.	Performance			Digestibility			
		FC	Gain	G:F ratio	% DE	DE in diets	% DN	DN in diets
Diets (D)	2	367.78	93.315	.00032	63.28	9576.0	28.164	530.64
Sex (S)	1	36030.	16406	.0260	.1001	3703.7	.0840	.2804
DS	2	459.94	101.40	.00007	1.6659	229.71	4.7649	.9199
Experiments (E)	1	3883.7	765.01	.01288	19.820	166.43	.0253	.0120
ED	2	34.140	37.803	.00041	.3024	277.44	1.7861	.0187
ES	2	47.321	1528.0	.00976	.3290	2170.2	.1768	.2789
EDS	2	1073.0	143.59	.00006	2.2072	3704.6	3.1978	.1576
Rats/SDE	12	205.46	24.068	.00010	.5011	823.09	2.3986	.1544
Total	23							

Source of Variation	Carcass Characteristics						
	DM	Ash	Protein	Fat	Energy	Energy / Body Wt.	Energy / Total Energy Digested
Diets (D)	.2284	.2038	36.348	16.724	11182.4	.0137	2.5611
Sex (S)	27.20	7.5713	.9721	10.627	102580.	.0627	4.5928
DS	.1918	.0446	1.0053	.1987	690.33	.0018	2.8365
Experiments (E)	282.29	17.647	358.13	358.44	7348.6	.5051	93.9312
ED	2.2667	.2464	7.9690	.0425	533.67	.0204	29.7037
ES	6.3757	.4648		1.1128	3952.2	.1604	.5013
EDS	.0861	.0164	1.0062	1.7470	551.16	.0018	.4659
Rats/SDE	1.1834	.2661	5.2752	7.5406	592.57	.0252	2.140